

GUIDELINE TO MARINE LITTER MONITORING



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The following guide was produced by the Sustainable Seas Trust through its African Marine Waste Network project as part of a consultancy with the Western Indian Ocean Marine Science Association

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Introduction

What is marine litter

Marine litter is composed of persistent solid materials, manufactured or processed by humans, that are subsequently discarded, disposed of or abandoned, and which end up in the coastal and/or ocean environments. With growing awareness of its detrimental effects, marine litter, especially plastics and microplastics, has increasingly been featured in the media and is increasingly part of the conversations of ordinary citizens as well as scientists and governments. If one is to manage the mounting problem of marine litter, thinking needs to be broadened to include litter on land; it is environmentally and economically more sustainable to deal with litter on land and in rivers before it gets to the sea. In this document, therefore, we use the term “litter” to refer to discarded items on land and in rivers (including plastic, rubber, metal, paper and processed wood, textiles and glass) that are likely to end up in the marine and coastal environments. By comparison, “marine litter” is used to refer to litter that is already in the ocean and the intertidal zones, or so near to the mouths of estuaries that they are practically in the sea. To avoid confusion, synonyms such as “debris”, “waste”, “trash” and “rubbish” are not used in this document.

A global challenge

It is widely cited that approximately 80% of plastic and other litter enters the sea from land-based sources (Jambeck et al., 2015), much of it carried to the sea by the rivers that drain the catchments in which people live, work, study and play. The remaining litter comes from ocean-based sources, including sea vessels used for recreation, fishing and transport as well as stationary platforms used for mariculture operations or oil and mineral extraction. It has been estimated

that 2.5 billion tonnes of municipal litter were generated in 2010 by 6.4 billion people living in 192 coastal and island countries (93% of the global population) (Jambeck *et al.*, 2015). Of this, 31.9 million tonnes were classified as mismanaged plastic litter, with an estimated 4.8 to 12.7 million tonnes of this entering the ocean. Once in the ocean, marine litter is transported vast distances worldwide and across international borders by wind and ocean currents, thus becoming an international problem with shared responsibilities.

The need to act

Although much of our current focus is on marine litter, on land as well, plastic and other litter have detrimental effects on human and environmental health and on economies, ranging from killing livestock to causing massive flooding. It is increasingly recognized, however, that plastics, metals, glass and paper also have inherent values as recyclable materials that present opportunities for job creation through the circular economy (Wagner and Broaddus, 2016).

Plastics degrade very slowly, requiring specific conditions to do so, and therefore persist in the marine environment. Marine plastic litter causes an estimated 13 billion USD in damage to global marine ecosystems every year (World Environment Day Outlook, 2018).

A further need to act is that most African countries are obligated as signatories to abide by several international treaties regarding the regulation and reduction of marine litter, including the UN 2030 Agenda for Sustainable Development. The Sustainable Development Goals (SDGs) include addressing marine litter and pollution targets through Goal 14 (target 14.1), with a particular focus on sources from land-based activities. Similarly, goals 6, 8, 9, 11 and 12 target untreated wastewater (6.3), resource efficiency (target 8.4), infrastructural development (target 9.4), municipal and other litter management (target 11.6), environmentally sustainable management of chemicals and litter (target 12.4), and overall litter reduction (target 12.5).

Current situation in Africa

Currently, data on litter production and mismanagement in Africa are not readily available; rarely will one find precise data for any country on how much litter is produced, where it is located and the composition, as well as the flow from source and the amount of litter entering the sea. Nearly all data on African countries are based on presumed correlations with population size, demographic patterns, socio-economic information and other surrogates, with very little direct measurement conducted to determine actual values.

Additionally, most African countries are developing more rapidly than the rest of the world. With improved health services, the rate of population growth exceeds any other continent (United Nations (Department of Economic and Social Affairs), 2014). Increased population growth, high urbanization rates, rapid economic development and increased per capita consumption all predict the amount of litter in Africa will soon become overwhelming if litter collection and management systems are not geared to cope with these changing circumstances.

Most major cities and towns in the Western Indian Ocean (WIO) region already generate significant amounts of litter, much of which easily reaches the sea. These include at least four major cities on the mainland coast of eastern Africa: Beira, Dar es Salaam, Maputo and Mombasa.

Marine litter monitoring

Management depends on measurement, setting of base-lines, development of appropriate strategies and monitoring the impact of those strategic actions and, where necessary, using acquired information to adapt management procedures to ensure actions are impactful..

A first step to improving management is to develop a baseline that provides measurements of the amount of litter being produced within each country, where it is being produced, how it is transported from its sources to enter the ocean and of its accumulation on the shores and in the sea. As most people occupy urban areas within municipal boundaries, those municipal areas that are in key catchments areas that drain into the sea offer excellent opportunities for development of baselines. Such baselines provide the foundations upon which to build management strategies. Regular monitoring of changes to the baselines indicate whether the strategies are working or not (after accounting for population growth or other factors that can affect the amount of litter discharged into waterways and the ocean). The monitoring system is a prerequisite to tracking the success of the management strategy and provides a measure of how well each country is meeting its SDGs.

A guide to a monitoring programme for the WIO region

To enable the countries of the Western Indian Ocean to become leaders in litter management the Western Indian Ocean Marine Science Association (WIOMSA) is partnering with Sustainable Seas Trust (SST) and its African Marine Waste Network (AMWN) project to initiate an observation and monitoring system for marine litter in Kenya, Mauritius, Mozambique, Seychelles and Tanzania. This programme focuses on developing monitoring programmes mainly for land-based sources of litter.

The guide has four primary components:

- i). i) A monitoring guide for the assessment of marine litter with methods and protocols. The guide includes methods/ protocols that may be used by the general public or other non-research trained persons.
- ii). ii) A description of the process and criteria for selection of participating institutions. This includes roles and responsibilities of institutions which will be responsible for a monitoring site.
- iii). iii) A process for selection of monitoring sites in the participating countries. This will include defining conditions that sites should meet to be included in the programme and selection process and criteria.
- iv). iv) A capacity building strategy for the participating institutions. The strategy will identify capacity and equipment needs for participating institutions.

2. Development of marine litter monitoring programmes

2.1 Objectives and expected outcomes

1. Develop a baseline

The first objective is to gather data to develop a baseline of current litter levels in the land environment. A baseline provides an indication of the initial state against which future change can be measured (for example an increase or decrease in litter). Baselines should be set over long enough time periods to minimize sampling error and large enough areas to be meaningful.

2. Identify hotspots and sources

Hotspots, or litter accumulation sites, can be identified by comparing amounts of litter in various places. Obvious hotspots are poorly managed landfills or illegal dumpsites from which litter readily flows down catchments and into waterways, or in some cases directly to coastal and marine environments. Litter source can be determined by examining the litter itself to ascertain its origin as well as by examining land-use and anthropogenic activities surrounding the sample area.

This provides valuable information which can be used to identify locations and major players that need to be targeted in a litter-minimization strategy.

3. Develop strategy

Based on data gathered, appropriate strategies must be developed to manage litter at source. While clean-up activities are important, more attention should be paid to preventing litter from entering the environment in the first place. This could include a combination of legally imposed compliance (in some cases development of new policies and regulations may be required) with actions at source (such as awareness, education and consumer behaviour modification initiatives) to prevent flow of litter to the marine environment.

Strategies must be linked to clear outcomes as well as have built-in metrics to evaluate their success. The SMART framework (an acronym for Specific, Measured, Achievable, Relevant and Time limited) provides a useful guide to setting goals when developing a marine litter strategy.

4. Measure change in litter over time

Once a baseline has been achieved, change in litter over time can be measured by regularly sampling in a uniform manner at selected study sites over an extended time period.

5. Is the strategy working?

After developing and implementing an appropriate marine litter strategy, marine litter monitoring can be used to determine if the strategy is successful. The baseline is the level of marine litter before the strategy is implemented and continued regular monitoring after the strategy is put into place will indicate whether the strategy is being successful or if it needs to be adapted. Simply measuring changes to the quantity of litter in work sites over time without considering changes elsewhere could be misleading. It is necessary, therefore, to quantitatively assess impacts of weather (particularly rainfall), changes in local population size, number of visitors to survey areas or changes in policy and/or enforcement, industrial or other developments are examples of variable to be included in the evaluations of impact.

Successful institutions will be expected to implement steps 1, 2 and 4.

What questions should the data answer?

Monitoring protocols are goal dependent, therefore, when designing a marine litter monitoring programme, it is necessary to consider what questions need to be answered. Depending on the questions asked, the type of data obtained and the way they are collected will differ.

Examples of Questions:

- How much litter occurs on the shores and in the waterways of the study sites?
- What are the principal sources?
- What are the transport pathways that litter follows from sources to coastal and marine environments?
- Where are the litter “hot spots” or areas where litter is most prevalent?
- Does the abundance and frequency of litter vary spatially or temporally?
- What is the composition of litter in terms of material type?
- What other variables affect input of litter into marine systems (e.g. changes in wealth, increase or decrease in municipal services, weather, economic activity, education).
- Will traps, booms or other collection systems be effective if placed along the routes?.

2.2 Key considerations for planning and execution

The following components and questions have been identified as vital to consider in order to design a successful marine litter measurement protocol. In response to each question SST has provided a recommendation.

Standardising collection protocols

A variety of methods has been developed to monitor litter in the environment, each adapted for different survey sites and litter types and suited to addressing different questions. There has been global acknowledgement of the need to standardize data collection protocols to enable data comparisons and identify global trends to correctly inform appropriate action (Hardesty and Wilcox, 2015; UNEP, 2016a).

It is **recommended** to adopt current protocols which have the benefit of already being trial tested. However, care must be taken to ensure chosen protocols are suitable for implementation in Western Indian Ocean contexts.

What is the minimum particle size to be measured?

Collecting larger litter items is easier, more convenient and more cost effective than smaller particles. The advantage of including smaller litter sizes in the protocol is that it would enable data gathering on microplastics. Many beach or other clean-ups tend to ignore microplastics, but the economic, health (Revel, Châtel and Mouneyrac, 2018) and environmental

impacts of microplastics are being increasingly recognized as is the need to monitor their abundance and implement a strategy to reduce their presence in the environment (UNEP, 2016b). Additionally, macro- and microplastics are transported differently, and therefore the abundance of macroplastics may not reflect the abundance of microplastics.

Litter size, particularly when considering plastics, will affect the protocols implemented through, for example, equipment used and the need for addition of a purification step to separate small litter fragments from bulk samples. See Table 1 for general litter size classifications.

Table 1: Litter size categories and corresponding diameters (mm).

Plastic Litter size category	Litter diameter (mm)
Macro	>25
Meso	5-25
Micro	<5
Nano	<0,001

Although there is no universally accepted definition of the size range of microplastics, in general microplastics are defined as particles or fragments of plastic less than 5 mm in diameter (Arthur, Baker and Bamford, 2009; Hidalgo-Ruz *et al.*, 2012; GESAMP, 2015; UNEP, 2016b). Some (Browne, Galloway and Thompson, 2010; Ryan *et al.*, 2018) classify microplastics as less than 1mm in diameter, however most papers use the former size range of 5 mm.

Due to their small size, microplastics are easily ingested by marine animals with purported extreme detrimental health effects which may include immunotoxicological responses, reproductive disruption,

anomalous embryonic development, endocrine disruption, and altered gene expression (UNEP, 2016b). This is caused by the leaching from microplastics of harmful chemical additives used in plastic manufacturing as well as the tendency of dangerous persistent organic pollutants (POPs) present in the environment to adhere to the surface of plastics (Andrady, 2011). These toxins then bioaccumulate in tissues of marine animals. Fish that have ingested microplastics can in turn be eaten by humans, although the side-effects of this are yet to be determined. Additionally, due to biomagnification, animals at the top of the food chain, such as apex predators, may suffer greater harm from a persistent toxin or pollutant than those at lower levels. The growing awareness and concern over these issues means microplastic studies are becoming more relevant (UNEP, 2016b).

Microplastics can be split into two categories: primary and secondary microplastics (GESAMP, 2015). Primary microplastics are manufactured in small size for a specific purpose, as industrial precursors for manufacturing, often called “nurdles”, or for household use, for example, “microbeads” which are used as exfoliants in cosmetic care products. Growing awareness of the negative impacts of microbeads has led to the banning in many countries of cosmetic and household products using microbeads. Secondary microplastics result from plastics in the environment breaking down into smaller pieces due to chemical and mechanical weathering by forces including wave action and UV radiation. This breakdown does not result in the complete degradation of plastic polymers, instead it simply breaks-up plastics into smaller pieces. Complete biodegradation of plastic molecules requires specific environmental

conditions (for example, prolonged exposure to high temperatures), which rarely occur in aquatic environments. Secondary microplastics also include those that are emitted due to wear and tear of products during normal use. Microfibres, synthetic clothing fibres that enter the waterways during washing, are a good example of microplastics in this category. Research has demonstrated the presence of microfibres and other microplastics in tap water (Orb Media) and the atmosphere (Dris *et al.*, 2015).

Different types of microplastics found in the Francisco Bay

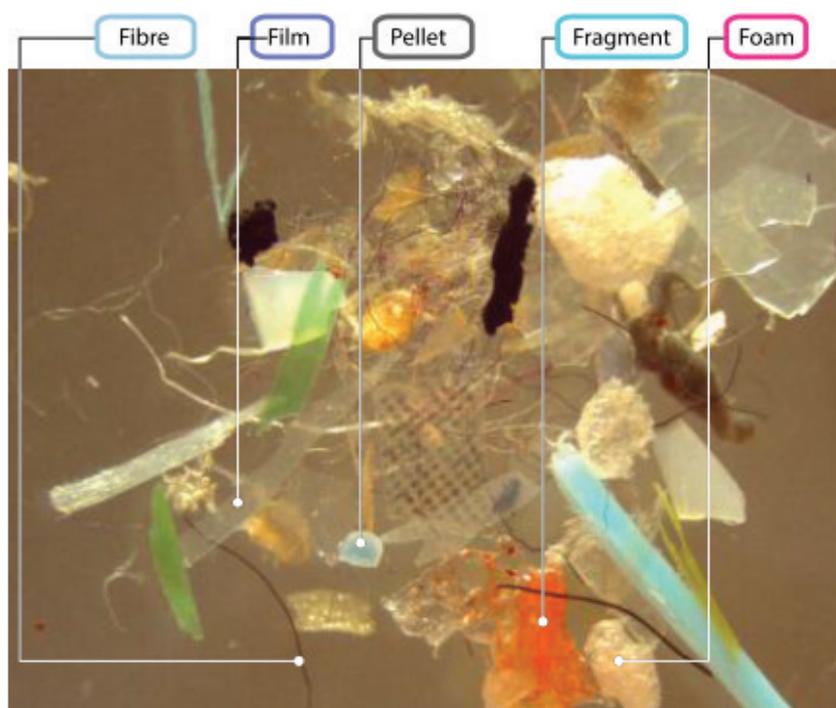


Figure 1: Different types of microplastics found in the Francisco Bay. Source: (UNEP, 2016b).

There is little work being done on microplastics in Africa outside of South Africa. This presents an excellent opportunity for the WIOMSA monitoring protocol, especially as data collected can be examined in tandem with that collected by the EAF-Nansen, a Norwegian vessel currently collecting data on microplastics in the waters of the Western Indian Ocean as well as the SA Agulhas II which is collecting data in the polar regions.

Microplastic sample collection

Due to their small size microplastics are difficult to identify visually and easy to overlook. Although it would increase survey effort, time, required expertise and equipment needs (Hanke *et al.*, 2013), it is **recommended** that microplastics are included in this protocol as they have attracted high global attention and may constitute human health risks. A monitoring programme can collect important information on microplastic abundance

over time up to a certain minimum visible size without high-tech equipment and with relatively cost effective methods.

Micro litter samples can be collected selectively, as a bulk sample, or as a volume-reduced sample (see Table 2) (Hidalgo-Ruz *et al.*, 2012).

Bulk samples and volume-reduced samples both require additional sample preparation and analysis in the laboratory. This has repercussions for capacity, equipment, costs and technical needs (see Chapter 4). Microplastic sampling methods that require a high degree of sample preparation are not recommended in the initial years of sampling, although some basic sample preparation (for example, seawater samples) can be undertaken with fairly low effort. Some institutions may choose to undertake additional sample processing, for example extracting microplastics from sediment samples.

Table 2: Microplastic sample collection types.

Sample collection type	Method	Sample consists of	Advantages (+) and Disadvantages (-)
Selective	Direct extraction from environment by naked eye (usually on sediment surface)	Microplastics only	<ul style="list-style-type: none"> • no need for sample processing • easy to overlook microplastics without characteristic shapes
Bulk	Entire sample taken without reduction during sampling	<ul style="list-style-type: none"> • Microplastics • Sediment or seawater • Additional organic matter 	<ul style="list-style-type: none"> • allows collection of microplastics that are otherwise difficult to pick up with the naked eye (eg: small in size or abundance, hidden by sediment particles). • sample requires additional processing.
Volume-reduced	Bulk sample volume is reduced during sampling (eg: sieving sediment samples or filtering seawater samples with nets)	<ul style="list-style-type: none"> • Microplastics • Sediment or seawater (less than the bulk sample) • Additional organic matter 	<ul style="list-style-type: none"> • allows collection of microplastics that are otherwise difficult to pick up with the naked eye (eg: small in size or abundance, hidden by sediment particles). • less volume than bulk sample. • sample requires additional processing.

Microplastic Sample Processing

Detailed chemical analysis of microplastics is ideal; however this requires specialized laboratory capacity. Having laboratory equipment and capacity to process microplastics has not been included among criteria for institution selection (see Chapter 3) because institutions can collect microplastics and then send them elsewhere for laboratory analysis. Processing and examination of nanoplastics collected from environmental samples are not yet feasible, therefore it is not recommended to include them in the monitoring programme.

According to a review by Hidalgo-Ruz *et al.* (2012), the four main steps of sample processing in the laboratory are:

1. Density separation

Typically, densities of sand and other sediments (2.65 g cm^{-3}) are heavier than those of plastic. Plastic particle density varies depending on the type of polymer and the manufacturing process (ranging from 0,8 to 1.4 g cm^{-3}). Plastic can therefore be separated from sediment by mixing the bulk sample with a saturated solution (concentrated NaCl, ZnCl_2 , sodium polytungstate, tapwater or seawater), and shaking for a certain amount of time (time period varies from 30s to 2 h according to the size of the sediment sample). Saturated NaCl solution (1.2 g cm^{-3}) has been recommended as it is non-toxic, inexpensive, easy to make and widely used (Hanke *et al.*, 2013), although this not suitable for polymers with a density higher than 1.2 g cm^{-3} (such as polyvinylchloride and poly-ethylene

terephthalate). Sediment sinks whereas plastics remain suspended or float to the surface of the solution (the type of plastic that floats will depend on the solution used). After the sample has been left to stand to allow the particles to settle (ranging from 2 min to 6 h), the supernatant containing the microplastics is then removed for further processing.

2. Filtration

Plastic particles are separated from the supernatant by passing the solution through a filter, usually with the aid of a vacuum. Filter paper pore sizes ranged from 1 to $2 \mu\text{m}$.

3. Sieving

Microplastics can be separated from samples by passing the sample through differently sized sieves (ranging from 0.038 to 2 mm). Sieve cascades of multiple mesh sizes were also used. This method can also be used to separate microplastics of different sizes.

4. Visual sorting

This is a necessary step to separate microplastics from organic matter and other items. This can be done by eye or with the use of a dissecting microscope. The following criteria are recommended for visually identifying particles larger than 1 mm:

- no cellular or organic structures are visible
- fibres should be equally thick throughout their entire length
- particles must present clear and homogeneous colours
- if particles are transparent or white they must be examined under high magnification and a fluorescence microscope

Preventing contamination in the laboratory

It is essential to take steps to avoid contamination of samples in the lab.

- Work areas should be wiped down and kept free from dust and other particles.
- Equipment must be washed with distilled water before and after sample processing.
- Clothing made of synthetic fibres must not be worn; cotton lab coats are acceptable.
- Samples must not be processed near a carpeted area.
- Air circulation must be minimized in the sampling area (e.g., close doors and windows).
- Ensure samples are exposed to air for a minimum amount of time and only when necessary (e.g., when transferring samples between containers).
- Always cover samples when not in use.
- Control samples should always be used to check for contamination. This involves running a procedural blank (repeating the experiment with only the solution and without any sample). An additional procedural control is to leave filter paper in Petri dishes uncovered and open to the air in your work area for the amount of time your samples would be open to the air. These controls should then be examined under the microscope to check for contamination. Cleaning should be repeated until contamination in blanks is zero or negligible.

Samples should be stored in dark locations with stable room temperature to prevent degradation.

How to identify and categorize litter

In order to determine the type of litter present, a system to identify and categorize litter must be developed. This system should be clear and comprehensive, but above all easy to use by surveyors.

UNEP (Cheshire *et al.*, 2009) reviewed thirteen marine monitoring protocols and separated their categorization systems by number of categories; low resolution (1–6), medium resolution (30–60) and high resolution (90+ categories). Most of the reviewed protocols utilized medium resolution categorization systems. In general litter is classified through a hierarchy by first identifying items by the material composition, then by their form or shape. Categorizing litter based on suspected sources has also been practised (Sheavly, 2010). It is important to remember that the properties of litter will affect their transport, and thus their representation in the data set, for example, dense plastics and glass bottles tend to sink and are therefore difficult to collect. Denser plastics are also more likely to remain closer to their source while buoyant plastics are easily transported great distances from source. It should be noted that some properties of plastics may change after long exposure to the marine environment, including appearance, buoyancy and density. For example, algal and other growths on buoyant plastics will make them heavier and cause them to sink

Material categories typically include (Cheshire *et al.*, 2009)

- Cloth
- Glass, ceramics and pottery

- Foam and sponge
- Hard plastics (moulded)
- Soft plastics and films
- Metals
- Rubber
- Paper and cardboard
- Wood
- Other (not necessarily based on composition)

Naturally, higher resolution studies enable more detailed analysis and interpretation of data which in turn allows a greater complexity of research questions to be posed as well as greater ease in identifying exact litter sources and targets for management strategies. However, a longer list of litter categories requires larger operational needs in terms of survey time, personnel training, analysis and data capture.

It is **recommended** that a medium resolution study be used (see example in Appendix 3). The intention is to incorporate enough categories to enable sufficient analysis of sources and hotspots to develop

relevant intervention strategies, while also remaining simple and streamlined for ease of use. Care must also be taken to ensure categories encompass litter types most likely to be found in African contexts. A checklist of litter categories relevant for use in the field in the study countries must be developed. These will be provided to selected institutions at the training sessions.

One method for checklist design that may be useful for the WIOMSA protocol is the use of photographs in the guide, as used by OSPAR (OSPAR Commission, 2010). The inclusion of photographs has the advantage of increasing the ease of litter identification and thus minimizing error, while also removing language barriers and extending the project to a greater number of participants without the need for translation into other languages. Using photographs or imagery in the WIOMSA litter categories is **recommended**.

Size Record size of each item. Minimum resolution is to allocate in to bin sizes of 100 µm

Type Plastic fragments, pellets, filaments, plastic films, foamed plastic, granules, and styrofoam

Shape For pellets: cylindrical, disks, flat, ovoid, spheruloids;
For fragments: rounded, subrounded, subangular, angular;
For general: irregular, elongated, degraded, rough, and broken edges

Colour Transparent, crystalline, white, clear-white-cream,, red orange, blue, opaque, black, gray, brown, green, pink, tan, yellow

CATEGORIES FOR MICROPARTICLES	
Material	Description
Material	Plastic fragments rounded
	Plastic fragments subrounded
	Plastic fragments subangular
	Plastic fragments angular
	cylindrical pellets
	disks pellets
	flat pellets
	ovoid pellets
	spheruloids pellets
	filaments
	plastic films
	foamed plastic
	granules
	styrofoam
Other	Other (glass, metal, tar)

Figure 2: Categories used to describe microplastics appearance. Source: (Hanke et al., 2013).

Microplastics

Microplastics are a heterogeneous group that vary widely in size, shape, colour, density, chemical composition and other characteristics (Hidalgo-Ruz *et al.*, 2012). It has been suggested that microplastics should be characterized according to their physical characteristics (size, shape and colour) as well as by polymer type (see Figure 2) so as to identify potential sources (Hidalgo-Ruz *et al.*, 2012; Hanke *et al.*, 2013). Classifying by physical characteristics may also yield important information on the potential of these microplastics to be mistaken as food sources by marine organisms and seabirds.

It is **recommended** that the following categories be used to classify microplastics:

Size – Classify into separate size bins (e.g., 1–5 mm) using graduated sieves with different mesh sizes.

Shape – Classify as fibre, fragment, pellet, film or foam.

Colour – Classify as red/pink/orange, blue/green, black/grey, brown, white, yellow, purple, transparent or other.

Ideally, identification should be undertaken in a laboratory with the use of a microscope or other methods. Additional highly specialized equipment has also been used to examine the polymer type of microplastics, which can yield important information on potential sources and pathways (Hanke *et al.*, 2013). For example, the use of Fourier Transform Infrared Spectroscopy (FT-IR), Raman

spectroscopy or other spectroscopy methods and focal plane array (FPA)-based imaging (Hidalgo-Ruz *et al.*, 2012) are increasingly becoming the norm in many microplastic studies. However, these methods may not be available in many laboratories (see also Chapter 5) and therefore the capacity to undertake this level of analysis has not been listed as a requirement for institutions participating in this monitoring programme.

For the purposes of this monitoring program it is recommended that a microscope, at a minimum dissecting microscope or stereoscope, be used to categorize microplastics by shape and colour. It has been reported that identification with microscopes tends to significantly underestimate the abundance of microplastics compared to identification with FT-IR, due to a tendency for white and transparent microplastics to be overlooked using the microscope and the limitation of the microscope in identifying particles smaller than 1 mm (Song *et al.*, 2015). Below 1 mm it becomes more difficult to distinguish microplastics from non-plastic material.

Therefore it is recommended that i) at minimum a dissecting microscope or stereoscope be used, ii) but only to quantify microplastics in the size range of 1 –5 mm (for the initial years of the survey; smaller size categories may be explored in subsequent years) and that iii) the presence of microplastics smaller than this size may be noted but cannot be reliably quantified using only these microscopes. To examine smaller size categories as

well as collect further information about polymer types present, it is possible that partnerships could be created with international laboratories and samples sent there for detailed analysis. If institutions are to undertake visual identification of microplastics under the microscope, surveyors will need to be trained on how to correctly identify and classify microplastics. Developing a guide of pictorial depictions of microplastics (see Figure 3) is useful for training. MERI's "Guide to Microplastic Identification" (Marine and Environmental Research Institute) can be used for training.

How to quantify litter?

Litter quantification is vital to compare between surveys and evaluate progress against the baselines. UNEP (Cheshire *et al.*, 2009) reviewed thirteen marine monitoring protocols and identified four principal methods for quantifying marine litter:

- Presence/absence of items within each litter type
- Counts of items in each litter type
- Weights of items within each litter type
- Volumes of items within each litter type



Figure 3: Spotters Guide to identifying microplastics. Source: Civic Laboratory for Environmental Action Research.

Each of these methods has advantages and disadvantages which are summarized in Table 3.

It is recommended to record both counts and weight for each litter category. Counts should be obtained first and then weights of each material category (e.g., plastic, glass, etc.). Litter maybe be biofouled by barnacles, algae, seaweed or be muddy or sandy. In this case items will need to be cleaned and dried before weighing to avoid errors in weight measurements.

What should the survey schedule be?

It is important to determine firstly the intended monitoring period of the entire study and secondly the frequency with which monitoring should be undertaken.

Longer monitoring periods (e.g., five years and longer) provide comprehensive data in which confidence can be developed while avoiding data biased by stochastic events. However, extended monitoring periods are

only possible with adequate funding, support and commitment from institutions involved, as well as quality control measures to keep data collection protocols constant over time despite the potential for personnel turnover. Additionally, care must be taken to account for other changes that may occur over time that could affect litter abundance, for example the rate of urbanization and population changes. This depends on the questions the data must answer and will influence the kinds of models that can be extrapolated from the data. The initial monitoring period of this study is three years, after which time institutions are encouraged to continue the monitoring with external funding.

Similarly, a suitable monitoring frequency must be developed to collect accurate data. Sampling should occur often enough to incorporate seasonal and other variations, for example, changes in rainfall, which may affect litter abundance in a sink at a given point in time. It is recommended that sampling events are conducted every two months

Table 3: Advantages and disadvantages of litter quantification methods.

Method	Advantages	Disadvantages
Presence / absence	<ul style="list-style-type: none"> • Simple. 	<ul style="list-style-type: none"> • Does not provide high enough resolution for meaningful interpretation.
Counts	<ul style="list-style-type: none"> • Easy to undertake. • Does not require specialised equipment. • Useful for remotely observed litter methods 	<ul style="list-style-type: none"> • Less useful when measuring objects from the same category that differ in sites (e.g.: nets). • Less useful when measuring fragmented litter.
Weights	<ul style="list-style-type: none"> • Relatively simple. • Fairly quick 	<ul style="list-style-type: none"> • Fouling of samples (eg: sand, algae) and whether the sample is wet or dry will skew results of weights. • Large objects are difficult to weigh. • Can be difficult to relate to management or risk assessment.
Volumes	<ul style="list-style-type: none"> • May be most useful for some items where easy to take measurements for calculations. 	<ul style="list-style-type: none"> • Not useful for most litter categories due to small sizes, non-uniform shapes.

What is the sampling effort?

In order to receive non-biased results, it is necessary to standardize sampling effort, for example the number and capabilities of people surveying litter at a given site at a given time. Additionally, some surveyors may be more diligent than others in counting and collecting trash. Keeping participant number, level of training and time spent per sample, as well as participant identity constant over surveys may avoid this problem. Comparisons between individual team members participating also serves as an important quality control mechanism. UNEP recommends standardizing sampling effort by using a fixed number of person hours per sample (Cheshire *et al.*, 2009). See also “Quality Control” and Chapter 4.

Quality control

High quality data must be collected to develop accurate baselines and comparative surveys. Therefore, incorporating measures of quality control into experiments and survey procedures is imperative to ensure data have been collected correctly and to minimize uncertainty. These can include both qualitative (representativeness and comparability) and quantitative (completeness, precision, accuracy) assessment of data. Bias during marine litter monitoring can enter the dataset in a variety of ways. For example, during beach cleans, observer bias may cause dull-coloured plastics to be overlooked in favour of brightly coloured plastics. The best means to ensure data quality in litter monitoring protocols is to ensure field personnel are properly trained and to conduct duplicates of litter characterization and quantification. It is also

important to avoid bias when selecting sites and or/ dates for sampling, for example, only selecting sites that are easy to reach, sites with more/less litter or dates with good weather.

Cost Effectiveness

Monitoring methods selected must obtain the most accurate data while keeping costs to a minimum. The cost effectiveness of each potential method must be examined prior to its implementation.

Equipment needs

These are listed by method in Section 2.3.

Staff training, manuals and tools

Refer to Chapter 5. A manual to be provided to participating institutions is being produced to support this document.

Centralized data storage

The capacity to collect and manage data using a reliable and tested system is a strong criterion for selection of the institutions to implement monitoring (see also Chapter 3). There is a need for the WIO region to build the data to enable the region to a) better manage litter and b) contribute meaningfully to enriching the data and understanding in Africa. Litter measurements need to be captured and processed in uniform ways. This can be done through a standard spreadsheet and/or database which each institution will be required to complete. The most affordable and accurate systems should be made available to enable all

researchers in the region to contribute to an African database and predictive modelling methods. Data collected by each institution in this monitoring programme will be sent to WIOMSA, which will act as the site for centralized data storage..

What site types should be examined?

Standard categories of sampling sites for marine litter include coastal deposition sites, biota, seabed and sediments and the water column. However, inland sources are major contributors to marine litter. Therefore, **it is recommended** that catchments, including waterways and land-based sources are monitored and that a diversity of ecosystems are covered.

It is **recommended** that the focus be on three site types namely,

1. Beach and rocky shore
2. Rivers and estuaries
 - 2.1 In water
 - 2.2 On shore
3. Point source
 - 3.1 In water
 - 3.2 On shore

Floating marine litter monitoring (visual observation or deploying nets and trawls from ships) has been excluded from this list due to high costs and highly variable data samples caused by the influences of ocean currents and wind patterns (Hardesty and Wilcox, 2015). Sub-surface marine litter monitoring (seabed sediments and water column) has also been excluded due to the need for specialized equipment (for example, sonar equipment, diving equipment and remotely operated vehicles) and trained personnel to carry out the protocol. Additionally, at-sea litter monitoring methods are also very expensive (Ryan *et al.*, 2009).

As multiple studies have shown that urban sites have higher associated levels of litter (Leite *et al.*, 2014; Ryan *et al.*, 2014; Willis *et al.*, 2017) it is recommended that coastal cities should feature in site selection. Rural and/or isolated sites should also be considered as they provide opportunities for comparison and may shed light on other issues, for example, socioeconomic factors (Hardesty *et al.*, 2016) and litter transport mechanisms.

3. Proposed monitoring programme for assessment of marine litter

Protocols will be listed by site type and criteria for site selection will be discussed for each.

General precautions and safety measures

When undertaking marine litter monitoring it is paramount to ensure the safety of surveyors in the field. A few general precautions to practice include:

- All surveyors should wear appropriate clothing and gear. This includes but is not limited to protective gloves, closed shoes and sun hats.
- Carry sufficient drinking water and an adequate first aid kit in the field and preferably include a qualified first aider in the survey team. Possible first aid emergencies could include cuts and abrasions, animal bites or stings and heat stroke.
- Check the weather and, where relevant, tidal charts before going into the field.
- Ensure the team has all necessary permission or permits to enter an area of land (for example, private land or a nature reserve) and perform monitoring.
- Undertake monitoring in pairs and/or groups and remain aware of the

surroundings. Notify a third party of the expected return time from the field and inform them when the team returns.

- Ensure monitoring does not damage the environment or disrupt local flora and fauna, especially endangered species.

3.1 Beach and rocky shore

Beaches are popular sites for marine litter monitoring, probably due to the wide number of beach clean community and awareness activities that attract many volunteers and potential data collectors. These surveys are a relatively easy monitoring method that can be undertaken with minimal training. It may be for this reason that many recommended beach survey protocols have become fairly standardized. Several protocols are referred to here, specifically those of NOAA (Opfer, Arthur and Lippiatt, 2012), UNEP/IOC (Cheshire et al., 2009), OSPAR (OSPAR Commission, 2010), CSIRO (Schuyler *et al.*, 2018) and the European Commission (Hanke *et al.*, 2013) as they are among the most widely recommended. These protocols were used to inform the method below.

3.1.1 Factors affecting litter deposition

Beaches are dynamic environments and a range of factors can affect their litter turnover. Factors affecting deposition onto beaches include local and offshore currents, beach slope, aspect, orientation, exposure, length and small-scale topographical features, tidal range, prevailing wind (strength and direction) and proximity to litter sources. It is also important to note that some of these factors may also be responsible for removing deposited litter from the beach, for example, tides may (re)claim litter and winds may blow litter off the beach. Litter may also be buried over time in beach substrate, and in turn be exhumed. Beach usage rate (which is affected by popularity and proximity to urban areas) and clean-up activity frequencies will also affect the amount of litter present. Beaches may therefore have differing rates of litter retention (retention rates will also differ between different types and sizes of litter). This has repercussions for the sampling frequency of beach monitoring.

3.1.2 Surveying beach litter

Standing stock vs Accumulation surveys

First, it is necessary to differentiate between Standing-stock and Accumulation surveys (see Table 4). In *Standing-stock surveys* beach litter is tallied and categorized within transects so as to determine the density of marine litter present at a single point in time. *Accumulation surveys* provide information on the flux (deposition of marine litter on to the beach over time, or number of items per unit length, per unit time) as well as assess litter type. The same stretch of beach is sampled repeatedly over a period of time and litter is removed during each survey event.

It is **recommended** that accumulation surveys are used to monitor the change in litter over time so as to gauge the rate of litter accumulation. By contrast, standing stock surveys do not provide such valuable information and an increase in the standing stock of beach litter may reflect a build-up of litter over time as opposed to a change in the amount of litter at sea (Ryan *et al.*, 2014).

Table 4: Contrasting Standing Stock and Accumulation Surveys. Modified from NOAA (Opfer, Arthur and Lippiatt, 2012).

Characteristic	Standing-Stock	Accumulation
Litter removed during surveys?	Optional	Mandatory
Time required per survey	Less	More
Is a set survey interval required?	100m or longer	100m or longer
Type of data that can be collected	<ul style="list-style-type: none"> Litter density (# of items / unit length) Litter material types 	<ul style="list-style-type: none"> Litter deposition rate (# and mass of items / unit length / unit time) Litter material types Litter weight

However, accumulation studies may be sensitive to sampling frequency due to varying litter turn-over rates of different items, requiring greater sampling effort and reduced sampling intervals. While frequent sampling reduces this sampling bias, these litter accumulation estimates are more variable than longer-interval sampling, and therefore a higher number of sampling events are required (Ryan *et al.*, 2009, 2014). A number of studies (Eriksson *et al.*, 2013; Smith and Markic, 2013; Ryan *et al.*, 2014) have found that longer intervals between sampling tend to underestimate the amount of beach litter compared to daily sampling. However, daily sampling can become difficult to implement due to high time and labour requirements. Therefore, it is **recommended** that short-term bouts of daily sampling be implemented. Litter is deposited onto beaches in tidal lines, therefore the preferred sampling unit to be used is per meter length of beach, as opposed to area.

Synoptic surveys

Beach surveys can be implemented as part of a synoptic survey – this is a broad overview of marine litter. This is a useful approach to gaining a general picture of marine litter along a country's entire coastline, as well as to identify regional hotspots and patterns in marine litter. Ryan *et al.* (2018) conducted a synoptic accumulation survey of 82 beaches along the South African coastline at three decadal intervals; 1994, 2005 and 2015. The study found that there tends to be more litter closer to urban areas. Hardesty *et al.*,

(2017) conducted a synoptic survey along the coastline of the Australian continent, providing a standing-stock survey of 175 beaches, and also found an increase in litter density with proximity to urban areas (as did Leite *et al.*, 2014) as well as a significant positive relationship with regional population. Both studies concluded that much of the marine litter therefore originated from local sources.

While the benefits of synoptic surveys to gain data for long coastlines are clear, whether they are feasible for the present study must be carefully examined. A survey of the entire coastline may be feasible in the smaller island nations of Mauritius and the islands of Mahé and Praslin of the Seychelles, as well as some of the Zanzibar islands of Tanzania which have coastal roads, but will result in a significant increase in time (several months), effort and transport costs in mainland countries.

3.1.3 Survey Protocol: Beach and rocky shore

In order to obtain information on litter flux, prior to beginning an accumulation study all litter on the beach study area must be collected and removed. Data should be collected from this clean-up (as a standing-stock study), however these preliminary data should not be incorporated into the accumulation study.

Microplastics

Macrolitter includes items which are larger than 25 mm and are easily spotted.

Equipment list: Beach macrolitter accumulation survey

Equipment	Approximate cost (US\$)	Notes
GPS	147	Smartphones have built-in GPS, accurate up to 5-8m, and could be an affordable alternative
Work gloves (x5)	23,5	At \$4,7 each
Refuse bags (x100)	23	
Demarcation flags	These can be made at low cost	
Measuring tape (50m)	18,17	
Newton scale	6	(5000g) To measure litter weight
Paint	2,4	Durable outdoor paint to mark large items that cannot be removed – a small tester pot can be obtained from a hardware store
TOTAL	85,37	

Before arriving at site

Surveying should take place at low tide. When planning monitoring schedule, consult tidal charts to determine the correct time for low tide.

Protocol: Beach macrolitter accumulation survey

1. Fill out the shore characterization sheet upon arrival (see Appendix 2.) The shore characterization sheet will require the surveyors to have gathered some prior knowledge about the survey area and the weather.
2. Measure study area and demarcate it. Permanent reference points should be established to ensure the same site is surveyed in future. Study length must be a minimum of 100m.
3. Prior to beginning a new accumulation study, all litter on the beach study area must be collected and removed. Data should be collected from this clean-up, however these preliminary data should not be incorporated into the accumulation study.
4. The following day, survey the entire study area by walking in a perpendicular or parallel walking pattern. It is recommended that a parallel walking pattern is used and that lengths of beach be divided between surveyors. The entire distance between the water's edge to the vegetation line at the back of the beach must be surveyed.
5. Every time a piece of litter is encountered it should be recorded on the data sheet in the appropriate category (see Appendix 5 for litter data sheet).
6. If an item is encountered that does not fit into a listed litter category, take a photograph, describe and record it in one of the sections marked "other".
7. If a litter item too large to be removed is encountered, paint a clear, recognizable mark at an easily visible location on the item with outdoor paint. This prevents the object being recounted in subsequent surveys.
8. Once recorded, litter items must be collected in refuse bags.
9. Weigh the litter items.

10. Once the survey is complete, correctly dispose of collected litter or store for further analysis.

11. Repeat the survey across the same stretch of beach at low tide the next day for a sample total of five to seven days.

12. This survey should then be repeated on the same stretch of beach every two months

Microplastics

Microlitter (<5 mm) should be sampled at the same time as macro and mesolitter so as to increase time efficiency. The simplest, most cost and labour effective method to sample microplastics in beach environments is to collect water samples in buckets from the surf. Microplastics can then easily be separated from seawater by sieving the bulk sample through a sieve of a certain mesh size, thus avoiding the need for additional sample processing as discussed in Chapter 2.2.

Preventing contamination in the field (Hanke *et al.*, 2013)

- As the majority of microparticles are plastic, the use of plastic equipment for sampling should be avoided. Metal or glass equipment is preferable. Equipment should be cleaned prior to sampling and covered during transport.
- Samples must be covered during transport, either by being placed in a container with a lid or by being covered with tin foil.
- Surveyors should minimize wearing any synthetic clothing and avoid garments that shed synthetic fibres readily (e.g., fleece).

Equipment list: Gathering seawater microplastic sample

Equipment	Approximate cost (US\$)	Notes
GPS	147	Smartphones have built-in GPS, accurate up to 5-8m, and could be an affordable alternative
10 L bucket	2,66	
Stacked sieve	~10	Can be made by stacking 2.5 L buckets with the bottoms removed and replaced with nets of varying mesh sizes
Glass jars (x5)	3	At \$0,6 each
70% Filtered ethanol (5 L)	36,80	This prevents organic matter that may be present in the sample (e.g., algae and plankton) from decomposing during analysis
Tin foil	3	To wrap the sample jars for transportation and storage
Labels	0,9	
TOTAL	203,36	

Protocol: Gathering seawater microplastic sample

1. Prior to sampling ensure all equipment and sampling jars have been rinsed with distilled water.
2. Use the 10 L bucket to collect seawater at areas where the depth is at least 45 cm. Sample should be collected after a wave has broken and sediment has settled.
3. The 10 L sample is then poured through a 5 mm mesh sieve. Wash the contents of the sieve into a glass jar as a volume-reduced sample.

- This should be repeated so that a total of 100 L is sieved.
- Fix the contents of the jar with ethanol and seal and label for transportation back to the laboratory.
- This entire procedure should then be repeated every two months.

Equipment list: Processing seawater microplastic sample

Equipment	Approximate cost (US\$)	Notes
Graduated sieves	~26,60	Using nets of varying mesh sizes
Petri dishes 55 mm (x10)	4,07	
70% filtered ethanol	36,80	This prevents organic matter that may be present in the sample (e.g., algae and plankton) from decomposing during analysis
Filtered water	1,70	Per litre. To clean equipment
Parafilm	37,17	(76,2 m x 5 cm) to seal Petri dishes
TOTAL	110,27	

Protocol: Processing seawater microplastic sample

- Prior to sample processing ensure all equipment have been rinsed with distilled water.
- Pour the sample through a stacked sieve with varying mesh sizes (in the initial years of the monitoring survey this can be a single sieve with a mesh size of 1 mm or less; in later years additional smaller size bins can be examined), taking care to properly dispose of the ethanol.

- With filtered ethanol, wash the contents of each net into separate Petri dishes and seal them.
- Examine Petri dishes under the microscope. Record abundance colour and shape. If possible, take photographs.

Possible additional monitoring protocol: beach sediments

Microplastics can be sampled visually on beaches; however, due to their small size, visual sampling is a time-consuming procedure and should only be performed in small transects. Alternatively, microplastics can be sampled in the sediment, a sampling method often employed in quadrats on sandy beaches. A sample is taken to a pre-determined depth, either within a single depth layer using a spoon or shovel, or through multiple depth layers using a corer. However, samples then require processing to separate microplastics from sand and sediment, as previously discussed.

Equipment list: Processing seawater microplastic sample

Equipment	Approximate cost (US\$)	Notes
GPS	147	Using nets of varying mesh sizes
Quadrats	Can be made at low cost	50cm x 50cm
Metal spoon	0,4	
Glass jars (x5)	3	At \$0,6 each
Stacked sieve	14,76	Of varying net mesh sizes
TOTAL	165,16	

Protocol: Gathering microplastic intertidal sediment sample

- Randomly select an undisturbed area on the beach at the top of the shore (strand line).

2. Collect samples from the top 5 cm of the sediment surface in a minimum 50 cm x 50 cm quadrat with a metal spoon.
3. Transfer samples into glass jars and seal them.
4. At least three replicates should be taken at each site. Each replicate should be separated by at least 5 m..

Equipment list: Microplastic sediment sample processing

Equipment	Approximate cost (US\$)	Notes
NaCl	6,53	Price for 1 kg
Graduated sieves	~26,60	Using nets of varying mesh sizes
Petri dishes 55mm (x10)	4,07	
Metal spoon	0,4	
Filtered water	1,70	Per litre. To clean equipment
Parafilm	37,17	(76,2 m x 5 cm) to seal Petri dishes
Filter paper 12.5 cm (x100)	8	Medium Speed 15–20 um
Stainless steel funnel	7,6	
Filtered ethanol (5 L)	36,80	This prevents organic matter that may be in the sample (e.g., algae and plankton) from decomposing during analysis
Tweezers	2,31	
TOTAL	142,71	

Protocol: Microplastic sediment processing – density separation (modified from Hanke *et al.*, 2013)

1. Clean work surface.
2. Clean equipment with distilled water.
3. Sediment sample must be placed covered into the oven at 90°C overnight or until dry. Record the weight of the dry sediment.
4. Make up saturated NaCl solution (1.2 g ml⁻¹) with filtered water. Pass solution through filter until no particles are visible in the solution.
5. Add a known volume (normally 500 ml) of sediment to a test tube / beaker using a metal spoon and add 200 ml of NaCl solution.
6. Place the stopper and agitate by hand, or stir beaker, for 2 minutes and leave to stand for 2 minutes.
7. Transfer the supernatant to pass through a stacked sieve to separate particles by size.
8. Repeat filtration five times with each sediment sample to ensure better recovery of buoyant debris.
9. Wash contents of sieve into Petri dish with ethanol and seal with parafilm.
10. Examine sealed Petri dishes under microscope. Record abundance colour and shape. If possible, take photographs.

Alternative Protocol: Microplastic sediment processing – density separation (based on Coppock *et al.*, 2017)

Coppock *et al.* (2017) designed a small-scale portable method for extracting microplastics with a reported mean efficiency of 95,8%, called the Sediment-Microplastics Isolation

(SMI) unit. Made from PVC piping, the reusable device contains a PVC valve to easily separate the supernatant from sediment for efficient removal during density separation with ZnCl₂ solution (1.5 g ml⁻¹) and cost around US\$65 to make.

Alternative Protocol: Microplastic identification with Nile Red

If their lab is equipped with a fluorescent microscope, surveyors may wish to use Nile Red to dye microplastics after density separation and visually identify them by their fluorescence under blue light as per the method laid out by Maes *et al.* (2017). In experiments this method was reported to have an average recovery rate of 96,6%.

3.2 Rivers and estuaries

Global land-based plastic emissions into the sea have been estimated at 4.8 to 12.7 × 10⁶ tonnes per year (Jambeck *et al.*, 2015). Recent papers report plastic litter export by rivers into the sea at between 1.15 and 2.41 × 10⁶ (Lebreton *et al.*, 2017) and between 0.41 and 4 × 10⁶ tonnes per year (Schmidt, Krauth and Wagner, 2017). As major transport systems to the sea, rivers carry litter into the marine environment and therefore should be monitored.

3.2.1 Factors affecting litter transport in rivers and estuaries

Variations in river length, catchment size, regional population, catchment characteristics, meteorological and climatic differences as well as the level of their

management all influence the amount of litter contained and transported in river basins (González *et al.*, 2016). Understanding river morphology and hydrology is essential when developing a riverine litter monitoring programme. River width, depth, transect shape, degree of sinuosity (river curves), braiding (channel division by bars) and anastomosing (occupation of rivers by large islands) will all affect how litter is transported through the system. For example, meandering rivers may deposit items in their bends and only release them during periods of peak water level or after physical degradation (González *et al.*, 2016). Human structures, such as channels, weirs and dams will also affect litter transport, as will the types of vegetation present on river shores.

Additionally, the characteristics of the litter itself will affect its own transport; in particular, the size, shape and density will affect litter buoyancy (along with river salinity). This means that the distribution of litter within the water column is never uniform, which will affect how riverine samples are taken. For example, sampling only at surface may only yield the smallest and most buoyant of the litter within a river. The representativeness of sampling will depend on the abundance of the sampled litter fraction, the type of equipment used as well as the duration of sampling (González *et al.*, 2016).

It is important to note that the amount of litter in rivers is highly varied as discharge regimes are susceptible to meteorological events and seasonal changes. Therefore, it is crucial that sampling frequency occurs often enough and over a long enough period to account for seasonal and environmental variability. Non-perennial or intermittent rivers also require a specialized strategy,

for example, quantifying litter present in the dry riverbed or before the onset of a flooding event. It is also important to consider the potential upstream sources of litter – samples intended to represent litter originating from a local site may also contain litter originating from other sources upstream that has been transported downstream to the sampling location.

3.2.2 Surveying riverine litter

The main methods for surveying three litter sizes in two river compartments (water body and river bank) was reviewed by the European Commission (González *et al.*, 2016) and is detailed below in Table 5. It is **recommended** that litter should be measured both in the river and on its banks to best approximate riverine litter load.

*Table 5: Methodologies for monitoring litter by size categories in different compartments of a river (González *et al.*, 2016).*

Size category	River water body	River bank
Macro	Visual observation Automated image acquisition systems Opportunistic sampling at structures (dams, weirs) Riverbed and bottom nets Booms / floats	Visual observation + collection
Meso	Booms / floats Manta trawl / nets	Visual observation + collection
Micro	Manta trawl / nets Pumps	Sediment samples

Monitoring the river water body

Visual observation of river litter requires trained professionals and can only reliably be used to identify litter larger than 2.5 cm in diameter. Additionally, observed surface layer changes with water turbidity and

required lengthy observation times can lead to observer fatigue and consequent error (González *et al.*, 2016). A better method is to collect floating and suspended litter for quantification. A range of sampling devices from nets, grids, booms and filters has been used to collect riverine litter at the surface and in the water column. Alteration in the size of net mesh controls the size of litter particles captured. But, it must also be noted that, while smaller net mesh allows the capture of smaller particles such as microplastics, so it increases the potential for net clogging and ripping. Concomitantly, the amount of sample collected increases while also decreasing deployment time until the net is full (thus altering the adequacy of representative sampling). Ideally, collection methods should be deployed to collect a representative sample for an established time period; however, deployment time per sample may vary according to river flow and the speed at which trash collects in the net.

In-river sampling can be “dynamic” – where a net or trawl is towed behind a boat; however, this method has additional logistics and costs, for example, boat hire. Alternatively, sampling can be “stationary” where the device is deployed from a bridge or river bank. In both cases, a flowmeter is desirable to capture local river flow data at the time of the sample to calculate the flow rate passing through the trawl and to calculate the trash load. Riverbed and pump-filtration systems have been excluded from consideration due to the extensive on-site logistics they require for installation, maintenance and recovery.

It is **recommended** that a weighted rectangular trawl is used (see Figure 4) for in-water surveying, as it can be used

in high-flow and low-flow conditions, can measure at different depths in the water column, and is also relatively inexpensive to make. This device has already been tested and compared to other methods by 5Gyres (5Gyres, 2016) and SST is using these trawls in a study of the Swartkops River Catchment outside Port Elizabeth, South Africa. 5Gyres experienced several difficulties with flow meters attached to the trawl, resulting in these data being discarded due to inconsistency. Nearby flow gauges maintained by municipalities were used instead to provide this data, although this data did not represent the flow at the point of the monitoring site due to distance. 5Gyres subsequently suggested either deploying a flow meter next to the trawl with a long pole or using the “orange peel method” which estimates river velocity by timing how long it takes a brightly coloured object to travel a specified distance downstream. While not the most accurate method, the orange peel method is very cost effective compared to a flow meter.

It is important to remember that the results gained from this monitoring device will provide an indication of the amounts of floating litter and litter just below the surface. To estimate total riverine output, data on litter carried on the river floor and at mid-water is needed. One of the advantages of using the weighted rectangular trawl is its ability to be deployed at varying depths in the water column

Monitoring the river bank

It is recommended that in addition to measurements in the river itself, litter on river banks is also monitored. These data allow determinations of how closely river bank and in-water monitoring reflect each other. Monitoring the river bank provides an indication of the amounts of litter deposited onto the river banks, which could be subsequently released from this sink into or back into the river water body by a storm or flooding event, aiding the development of a proxy for the amount of litter in a watershed. River bends and flood plains are likely accumulation sites.

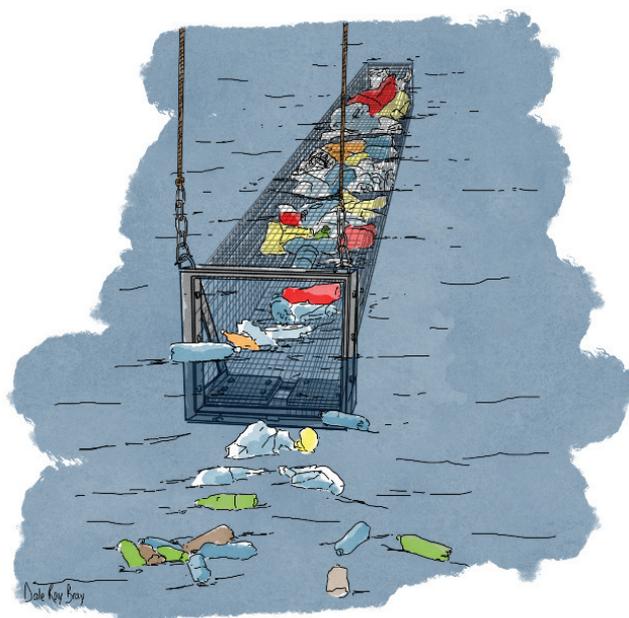


Figure 4: Left - Rectangular trawl (silver) and weighted rectangular trawl (blue). Source: 5Gyres (2016). Right - illustration of rectangular weighted trawl being deployed. Source: Dale Bray, SST.

3.2.3 Survey Protocol: Rivers and estuaries

Monitoring the river water body

The following method is the SST weighted rectangular trawl protocol developed for the Swartkops project from a modified method by 5Gyres (5Gyres, 2016).

Equipment list: River

Equipment	Approximate cost (US\$)	Notes
GPS	147	Smartphones have built-in GPS, accurate up to 5-8m, and could be an affordable alternative
Work gloves (x5)	23,5	At \$4,7 each
Refuse bags (x100)	23	
Rectangular trawl	145	Materials and construction (metal, weights, welding, etc)
Net	Macro- net	1x2m Could also be made from recycled fishing nets
	Neuston net	1x2 m
Stabilizing line(s) (20m)	31,4	Strengthened cable (\$1,57 per meter)
Fastening shackles (x4)	4,69	
Flow Meter	220	Purchasing of flow meter can be avoided selecting a site with a nearby flow meter or by using the "orange peel" method.
Stopwatch	-	Most cell phones have built-in timer
Traffic Cone (x2)	5,34	To control traffic on busy bridges if necessary
TOTAL	621,80	

Additionally, funds may need to be spent on acquiring the appropriate permitting for sampling.

Before arriving at site

- The rectangular weighted trawl must be constructed. The 45 cm x 45 cm frame is made from galvanized steel with two 5kg removable weights at the bottom and two metal loops for attachment to stabilizing lines at the top. A net is attached on one end. See Figure 4 for photographs and Appendix 6 for structural drawings.
- Permits may need to be obtained from traffic authorities before undertaking monitoring from bridges on busy roads and from local municipalities to conduct sampling.

Protocol: Monitoring in water macro- and meso- riverine litter

- Fill out a river site characterization sheet.
- River flow rate must be determined (ideally from the fastest flowing point of a river) using either a) a flowmeter deployed next to the trawl, b) a nearby flow meter, or c) 5Gyre's "orange peel method".
 - A pole or cable with flow meter attached must be used to lower the flow meter into the water in the vicinity of the trawl. Care must be taken to keep the flow meter steady and the operator must insure that no contact is made with floating matter that could affect the flow meter's measurement.
 - If there is a flow meter in the vicinity of the sampling location (usually attached to municipal or private water monitoring stations) access to this river discharge data should be requested from the relevant bodies.

- c. Select a location at the survey site with laminar river flow. Establish a known distance in the sampling area, parallel to river flow. Deploy a brightly coloured, easily visible object into the water at the most upstream point of the known distance and start the timer simultaneously (take care to only start the timer once the object is in the water). Record the amount of time it takes for the object to travel to the most downstream point of the distance.

River flow rate (in m³ per sec) entering the trawl is

$$Q_T = vA(d/h)$$

- Where:
- Q_T = Total flow through the trawl (m³ s⁻¹)
 - v = Velocity of the water through the trawl (m³ s⁻¹)
 - A = Cross sectional area of the opening of the trawl (m²)
 - h = Height of the opening of the trawl (m)
 - d = Depth of the water relative to the bottom of the opening of the trawl (m)

3. Fix the trawl securing lines by wrapping each securing chain line around a bridge post and securing with a carabiner or shackle and THEN slowly lower the trawl from the bridge into the fastest flowing point of the river.
4. Deploy the trawl for a duration of 3–15 mins for fast flow (more than 0.23 cubic meters per sec) and 30–60 mins for slow flow (less than 0.23 cubic meters per sec). The duration for which the trawl is deployed must always be recorded.

5. After this time has elapsed or when the net is full, remove the trawl from the water and empty the net.
6. Discard organic matter and record all captured litter on the litter data sheet (see Appendix 3 for an example).
7. This entire procedure should be repeated at least three times every two months.

The following equation can be used to determine the trash load of rivers/waterways:

$$R_T = QV/(Q_T t)$$

- Where:
- R_T = Creek trash rate during sampling period (gal/min)
 - Q = Stream average discharge during the sampling period (m³ s⁻¹)
 - V = Volume of trash collected (gal)
 - Q_T = Flow rate through the trawl, as previously calculated (m³ s⁻¹)
 - t = Time of the sampling period (min)

Note that this equation determines the litter load of the entire river. By lowering the trawl down the water column and sampling at different depths, different litter loads would be determined (Section 3.2.2.). The average of these different values would provide a better approximation of the actual value although this will require additional sampling at each site

Microplastics

Microplastics can be easily included in this protocol by decreasing the size of net mesh as previously discussed. A review of thirty-three papers using trawls and nets to investigate pelagic microplastics showed that the majority of studies used net mesh sizes between 300 and 390µm (Hidalgo-Ruz *et al.*, 2012).

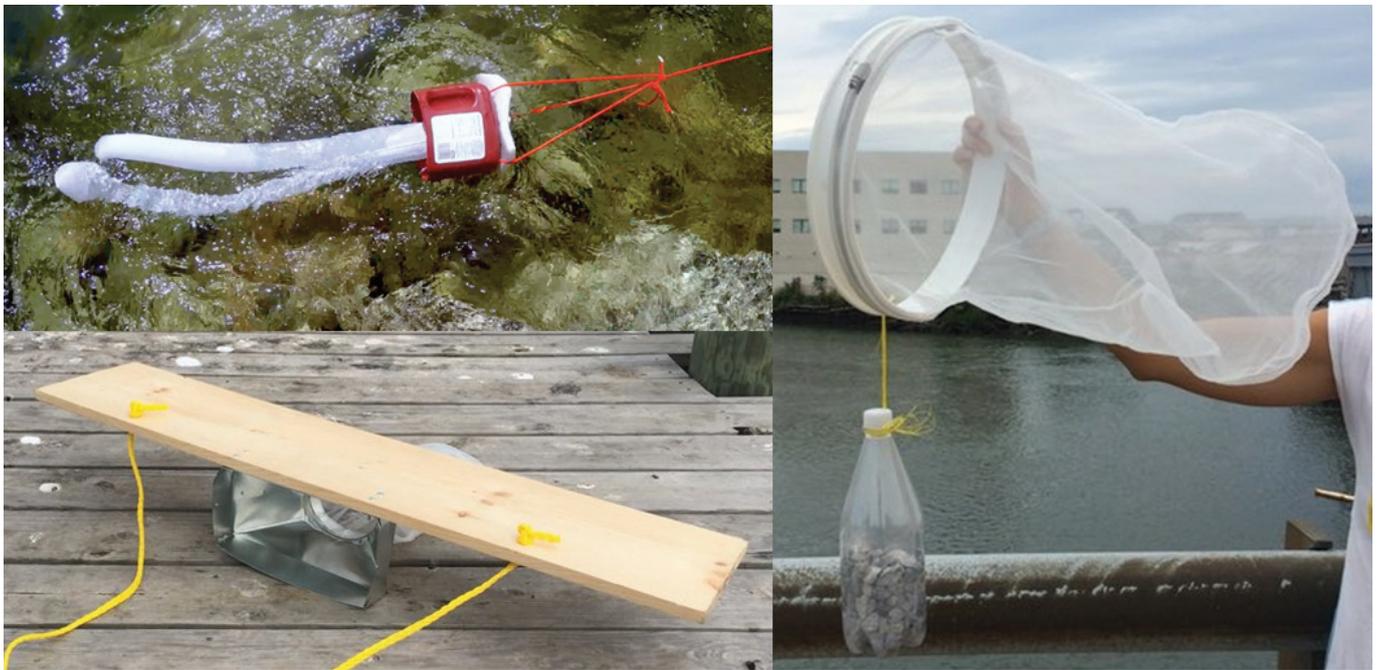


Figure 5: Three trawls made from recycled or easily available materials. Top left – “Baby Legs” trawl made from tights and a recycled bottle designed by Max Liboiron, Source: Civic Laboratory for Environmental Action Research. Bottom left – “Hardware Trawl” made from a wooden plank and air-conditioning duct designed by Marcus Eriksen, Source: Testing Our Waters. Right – “Bridge Trawl” made from bucket rim and recycled PET bottle, Source: Testing Our Waters.

Recycled alternatives

A number of organizations have created, tested and made publicly available designs for cheap trawls made out of recycled or easily sourced materials, three of which are pictured here (Figure 5). Testing Our Waters has also listed designs for trawls made of 3D printed parts.

Monitoring the river bank

An accumulation survey as described for macrolitter beach monitoring could be applied here. The sample area will take place between the water’s edge up to the extent of the most prominent flood point.

Possible additional monitoring protocol: mangroves

River bank vegetation presents an obstacle to monitoring on river banks. In estuarine areas this vegetation may include mangrove systems. Ideally river bank accumulation surveys would be conducted at sites with relatively little thick vegetation cover, however mangroves could present an interesting site type for surveying.

Coastal mangroves are vital habitats that provide a range of ecosystem services. These include providing raw materials and food, shelter and nursery grounds to a huge diversity of species, sequestering atmospheric carbon and serving as a physical barrier to protect the coastline against storms, wave energy, erosion and flooding (Barbier *et al.*, 2011). Importantly, they act as a natural biological filter for anthropogenic litter and a buffer between land and sea for litter. Much research has been conducted on the effects of oil and heavy metal pollution; however, few have examined the amounts of plastic trapped in mangrove systems. This provides an excellent opportunity for WIOMSA to take a lead, especially as valuable mangrove ecosystems are being lost globally at a rate of 2.1% annually (Valeila, Bowen and York, 2001).

Mangrove habitats present a challenge for monitoring due their navigational and sampling difficulty. Initial research identified few studies monitoring mangrove ecosystems for macro- and mesolitter.



Figure 6: Three mangrove species showing differences in root systems. A – Red mangrove, *Rhizophora mangle* (Source: Amble Resorts); B – White mangrove, *Laguncularia racemose* (Source: Mongabay); C – Black mangrove, *Avicennia germinans* (Source: Dreamstime.com).

Type of mangrove species present may affect sampling ability due to varying degrees of root system impenetrability (see Figure 5). These complex root systems trap litter, especially plastic bags and PET bottles. Cordeiro and Costa (2010) demonstrated the plastic retention of mangroves is long term, ranging from months to years.

Macrolitter sampling in mangroves

Protocols for beach monitoring can be applied in mangrove systems, but may need to be undertaken in smaller transects (Cordeiro and Costa, 2010).

Microplastics

Microplastics have been surveyed in the sediments of mangrove systems in SE Asia. Mohammed Nor & Obbard (2014) examined mangroves in Singaporean sites and Barasarathi *et al.*, (2014) studied mangroves in Malaysian sites. Both focused on microplastics in the sediment with some sampling differences, detailed in Table 6 and both used Thompson *et al.* (2004)'s filtration method with some modifications. Filtration of mangrove sediments for microplastics is challenging as mangrove sediments typically consist of fine silts. Therefore, it is **not recommended** that microplastics be surveyed in mangroves for this monitoring programme, although they could be examined with the use of an SIM unit.

Table 6: Differences in sampling in two microplastic studies in Malaysian (Barasarathi *et al.*, 2014) and Singaporean mangroves (Mohamed Nor and Obbard, 2014).

	Malaysian study	Singaporean study
Quadrant size	50 cm x 50 cm	1,5 m x 1,5 m
Number of quadrants	3	3
Distance between quadrants	10 m	2 – 3 m
Distribution of quadrants	Starting randomly 50 m from low tide mark	Undisturbed areas
Sediment sampling depth	1 – 5 cm	Top 3 – 4 cm

3.3. Point sources of pollution

Identifying the original source of litter currently in beach and river environments can be very difficult as this litter most likely originates from multiple diffuse sources, also known as non-point source pollution. By contrast, point source pollution is defined as “any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ship or factory smokestack”. It is **recommended** that, as localized points of anthropogenic litter output, point sources be

monitored. Surveying point source litter offers a simple way to directly monitor the impact of a known output into the environment. This can make the extrapolation of litter source easier, as well as identify key locations to be targeted with preventative measures.

Dumped litter can accumulate in drain and storm water systems with devastating results. By blocking city drainage systems, trapped litter can contribute to both flooding and the spread of disease. This was the case in the 2011 flooding in Accra, Ghana which resulted in the death of fourteen people, 17 000 people losing their homes and a further 43 000 people being affected by the floods, as well as damage to roads, waterways and bridges and causing the spread of disease. In addition 100 incidents of cholera were identified a week after the flooding occurred (UNEP, 2015). Similar events have been reported in other parts of the world.

For the purposes of this monitoring programme, point sources of localized litter discharge into waterways, for example sewerage or storm water drains, as well as solid litter dump sites where solid litter may be transported by wind or water to the sea, will be examined. Nurdles (primary microplastics) can also be lost from industry and manufacturing point sources through mismanagement and spillage to enter drain systems and waterways

3.3.1 Surveying point source litter

It is recommended that methods already discussed, namely trawls for riverine litter monitoring and standing stock surveys for beach monitoring, are applied here for point source monitoring in water and on land respectively. This removes the need to purchase additional equipment or for further training.

3.3.2 Survey Protocol: Point Source

Monitoring point source in water

Where possible, a weighted rectangular trawl can be used to monitor point source discharges into waterways, as discussed in Chapter 3.2. To determine the output of the point source the trawl should be deployed directly downstream in close vicinity to the point source. This monitoring could also be conducted at the same time as in water riverine litter monitoring, simply by including conducting trawl surveys downstream of a point source. Using trawls for in-water point source monitoring also has the advantage of providing the facility to measure microfibrils which enter waterways from wastewater.

Possible additional monitoring protocol: Litter trapping devices

Litter booms and floats are surface-floating litter catching barriers that may divert litter to a collection cage (González *et al.*, 2016). Grids over drain systems are also implemented to collect litter from point sources or in rivers and streams (see Figure 6). As these devices prevent litter from traveling downstream in rivers they are primarily deployed long-term in rivers or at point source outlets into rivers as a measure to mitigate pollution through the capture and subsequent removal of riverine litter. Responsibility usually falls on the local municipality to maintain the device and remove collected litter which, if not done, could cause obstacles to natural river flow. The litter trap may have a removable section or litter can be removed using cranes, clamshells deployed from boats or with nets.

Litter trapping devices may also be used for monitoring purposes. Gasperi *et al.* (2014)

used an existing network of litter booms to measure floating litter at a large regional scale in the River Seine, France. Booms, floats and/or grids could also be used for the purpose of measuring point source discharges into waterways by deploying the device directly downstream of the point source.

If there are existing litter trapping devices already in use in waterways that would be suitable for litter monitoring, the relevant municipal or governmental bodies should be approached to request permission to use the devices for monitoring. Alternatively, a basic litter boom can be made with recycled items and building materials. The amount of building material needed will vary according to the size of the river as well as the expected amount of litter it will need to capture.

The ideal litter boom should:

- Be economical to construct and operate
- Have no moving parts

- Not require an external power source
- Have a high removal efficiency
- Be self-cleaning
- Not increase flood levels in the vicinity of the structure (Armitage *et al.*, 1998)

It may also be important to construct non-permanent booms from materials that are not highly valued economically as well as to deploy the booms in areas where they will not be susceptible to vandalism or theft.

Equipment list: Litter float

This equipment list was created with a self-made design in mind, the easiest design being similar to the litter float depicted in the top left of Figure 7. A more sophisticated design (such as that depicted in the bottom of Figure 7) would require the addition of PVC piping (50 mm diameter at US\$1,57 per meter) and a net or collection cage.



Figure 7: Top left - A litter float (Source: United States Environmental Protection Agency). Top right - A collection grid (Source: Science News for Students). Bottom - A "Bandalong" litter boom and collection cage showing deployment at point source (Source: Storm Water Systems).

Additionally, permits may need to be obtained from the authorities to deploy long term structures. Deploying a litter float at an angle across a river allows the litter to collect at the most downstream point and enables easier litter removal. Hand nets are a cheap method to aid in this collection process.

Microplastics

As litter traps are designed for long-term deployment, the mesh size of the collection cage is usually not designed to retain small particles and is therefore not feasible for monitoring microplastics.

Monitoring point source on land

Small, local and illegal dumpsites on land, in catchments and coastal and urban environments can also be surveyed. A method similar to those suggested for standing stock beach monitoring could be applied here.

Equipment	Approximate cost (US\$)	Notes
GPS	147 (basic hand-held research GPS)	Smartphones have built-in GPS, accurate up to 5-8m, and could be an affordable alternative
Work gloves (x5)	23,5	At \$4,7 each
Refuse bags (x100)	23	
Shade cloth	10,36	At \$1,73 per meter. Recycled hose (e.g., retired fire hose obtained from a fire station), or HDPE pipes can also be used
Recycled plastic bottles	-	
Anchoring line (6 m)	1,44 / 12,24	Rope at 0,24 / chain (5 ml) at 2,04 per meter
Concrete anchor	5,38	For a 50 kg bag (optional)
Sundries	10	Zip ties, screws, etc.
TOTAL	220,68	



Figure 8: Left - Litter float made from recycled PET bottles and shade netting. Right - Litter float made with HDPE pipe. (Source: John Kieser, PlasticsSA).

3.4 Additional monitoring methods to be considered

These have been included in this document to act as an ideas base for additional research outside of the initial phase of this monitoring project.

3.4.1 Remote sensing: Aerial imagery and drones

Satellite imagery and images captured from flying craft including aeroplanes and Unmanned Aerial Vehicles (UAVs), more commonly known as research drones, can be used to survey litter present on river banks, beaches and water surfaces by capturing high-resolution imagery, and create comprehensive maps with GIS. These methods also identify land use data, municipal infrastructure routes, urban settlements and hydrological profiles. Multi- and hyperspectral band analysis is used to directly detect areas with high densities of plastic.

3.4.2 Mobile apps

Mobile applications present an easy and accessible way to harness citizen science for the collection of data on marine litter. These apps allow the easy capture of survey and litter data, often including photographs using smartphones. Several organizations have developed mobile apps to collect data during beach clean-ups (as well as other land-based and ocean-based clean-ups), for example CleanSwell by Ocean Conservancy, Dive Against Debris by Project AWARE and Marine Litter Tracker by NOAA. These apps are not standardized; each records and reports litter data in a variety of ways. It has been shown that marine litter data collected by citizen scientists can be of equivalent quality to those collected by researchers (van der Velde *et*

al., 2017). Should mobile applications be used for a larger scale long term monitoring program, the methods would have to be standardized (i.e., select a single mobile application for promotion and propagation).

3.4.3 Ghost gear

While about 80% of marine litter arises from land-based sources, the remainder originates from sources at sea. There has been global concern voiced about the contribution of the fishing industry to marine litter, particularly abandoned, lost or discarded fishing gear (ALDFG). ALDFG is at least four times more likely to impact marine life than all other forms of marine litter combined. In 2009, FAO and UNEP estimated that 640 000 tonnes of fishing gear are lost or abandoned in our oceans each year. Today, the number is likely to be much higher.

The ability of ALDFG to continue to capture fish, turtles, marine mammals and diving birds is often referred to as 'ghost fishing' which has detrimental impacts on fish stocks, food security and endangered species and benthic environments. Causes of ALDFG include excessive fishing efforts, gear conflicts, extreme weather, operator error and deliberate abandonment. It is also linked to illegal, unreported and unregulated (IUU) fishing as IUU fishers are more prone to discard their fishing gear at sea. Ghost gear costs governments and marine industries hundreds of thousands of dollars annually in clean-up expenses and lost fishing time. In recent decades, with expansion of fishing effort and fishing grounds and the inclusion of synthetic, more durable and buoyant materials in the manufacturing of fishing gear, for example plastic, ghost fishing is on the increase as lost or abandoned gear accumulates (Gilman, 2015).

4. Site Selection

There are a range of factors that influence the amounts, types and sources of litter found in specific areas that should be considered when selecting sites. Selecting a study site and the kinds of data that need to be collected about the site depend on the questions to be answered (see also Chapter 2).

Data to be collected about suitability of study sites include information on:

- Roads and railways
- Rivers
- Watersheds
- Vegetation (biome types)
- Population (local and regional) and building density (demographic patterns)
- Land use (e.g., recreational, agriculture, industrial)
- Localities of solid litter dump/landfill sites
- Wind direction and intensity
- Rainfall patterns and run-off
- Human behaviour
- Legislation and enforcement

It is important that site reconnaissance be done prior to sampling to determine whether a particular site is suitable. Beyond the characteristics listed for each suitable environment type, sites should be selected as randomly as possible so as to avoid biasing data.

The initial focus of this monitoring programme is on coastal urban areas.

4.1 Beach and rocky shore

- Clear, year-round access for surveyors.
- Exposed to the open sea.
- Be composed of sand or gravel.
- No regular clean-up activities.
- Accessible for the removal of litter.

- Low to moderate slope.
- Be a minimum of 100 m in length.
- Be a minimum of 5 m in width.

4.2 Rivers and estuaries

- Clear, year-round access for surveyors and for litter removal.
- Ideally the monitoring site should not be influenced by any tidal currents. In cases where sites that are affected by tides must be selected (e.g., estuaries), sampling should occur at the same tidal phase to ensure reproducible results.
- The river must be wide and deep enough for trawls to be submerged and to gain accurate data from flowmeters (if used).
- Catchments need to be large enough and appropriately placed to be of significance in draining heavily polluted areas.
- The rivers flow rate must be fast enough to have water moving into and out of the trawls.
- There should be several road-crossings along the length of the river. Ideally these crossings are bridges from which the trawl could be deployed directly into the fastest flowing point of the river.
- The bridge must be structurally secure with minimal traffic and ample space for safe monitoring set-up.

- Potential upstream sources of litter must be a consideration.
- Ideal deployment locations for equipment must be derived from flow measurements, taking into account the river transect, influence of wind and the availability of deployment structures and accessibility.

As the Seychelles does not have any major rivers, the use of trawls to monitor river water bodies will have to be excluded in this country.

4.2.1 Mangroves

Mangrove areas in Mozambique, Tanzania and Kenya are prevalent. Many are close to large coastal cities (for example, Maputo, Dar es Salaam, Mombasa) (see for example Figure 7). Ensuring that sampling sites have clear, year-round access for surveyors is vital due to navigational difficulty and tidal influences in mangrove habitats. Data on mangrove species types at each proposed survey site must be acquired.

4.3 Point sources of pollution

Point sources are likely to be found in urban environments; therefore cities and towns are to be examined for selection of point source sites. Significant point sources are often found where people live, work, study, play and hold other activities, as well as in industrial areas, and also should include sewerage system outlets located in more remote areas. Point sources of litter introduction in rivers would be major outlets of artificial waterways. These include (but are not limited to) sewage, pipe and stormwater outlets. For health and safety reasons raw sewage outlets are to be avoided. Point sources of litter on land include illegal dumpsites. Such sites will occur in and around areas where municipal disposal services are limited.

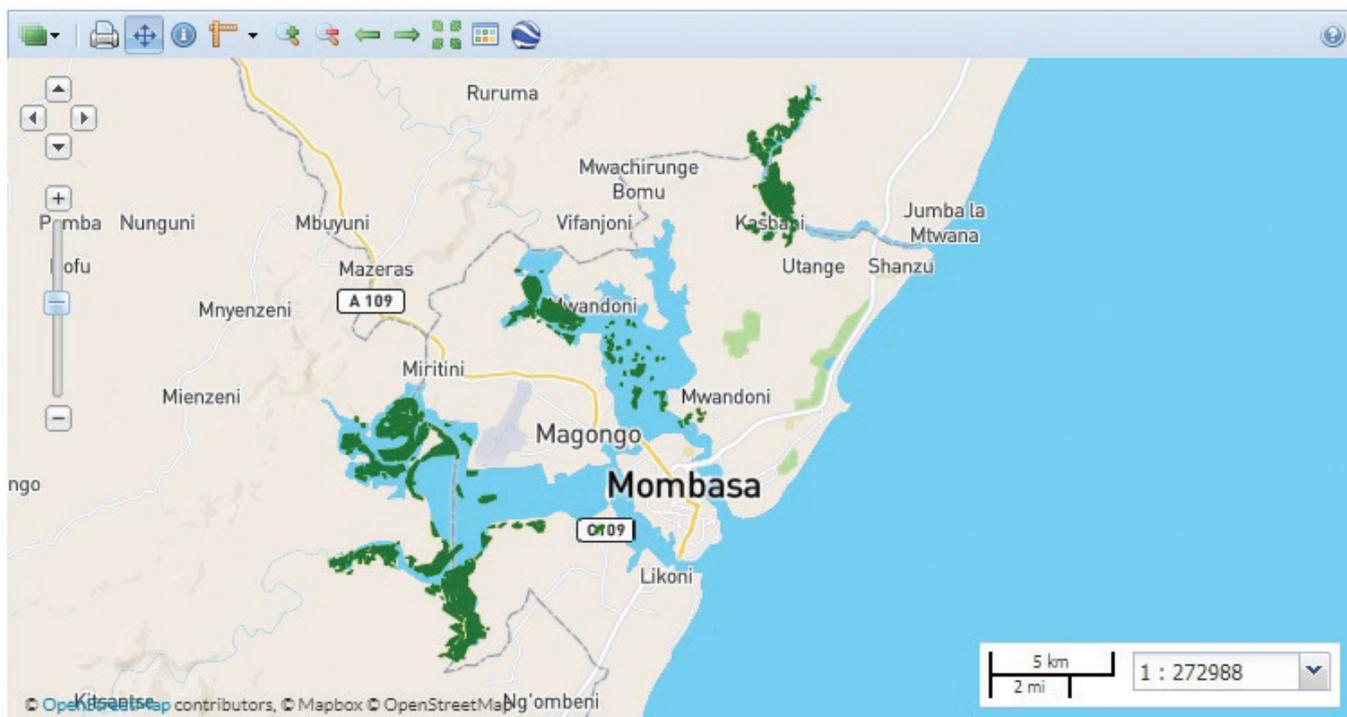


Figure 9: Map of mangrove systems (in green) in the coastal city of Mombasa, Kenya. Source: RCMRD Geoportal.

5. Selection of participating institutions

Institutions must be selected to undertake the implementation of the monitoring protocols. The selection of institutions will be made by a team consisting of members from WIOMSA and the associated funding bodies for this project. A maximum of five institutions will be selected, one in each of the five study countries; Mozambique, Tanzania, Kenya, Mauritius and the Seychelles. Selected institutions will participate in a training session hosted by WIOMSA.

1. Specific research activities of institutions should be designed to contribute to any of the following objectives:

- a. Collecting data on marine, riverine, estuarine or point source litter in coastal areas of the Western Indian Ocean region, including quantification and identification of litter, to develop a baseline.
- b. Identifying litter sources and hotspots on land.
- c. Tracking and monitoring plastic litter as it is transported from source to sea, including quantification and identification of litter in coastal areas.
- d. Quantifying and monitoring changes to macro-, meso-, or micro- litter and plastics. (Note: It is not required for institutions to have capacity to process and analyse microplastics).

2. Applying institutions should submit a report detailing the following:

(The entire application should be no longer than 10 pages, not including Appendices).

a. Background knowledge and awareness of the issues

- i. An overview of the current knowledge in and history of work on marine litter¹ in their country.
- ii. Information on any on-going monitoring programmes on marine litter or other pollution within the institution.
- iii. A section indicating knowledge of global and in-country monitoring programmes on marine litter.
- iv. An explanation of why the institutes' representative countries need a marine litter monitoring program.

b. Research proposals and technical capabilities

- i. Proposed methods to monitor marine litter and a statement of the techniques the personnel will require to perform

¹ Here "marine litter" includes both sea and land based sources.

such monitoring as well as a description of how data quality will be checked.

- ii. Identify and justify priority sites selected for monitoring in representative country. Considerations may be based on social, economic or environmental importance of sites as well as the strength of the site to act as a national indicator of the litter problem.
- iii. Identify and justify sampling schedule.
- iv. Detailed plan to undertake monitoring in the first year, with less detailed plans for second and third year.
- v. Plans to continue monitoring after the initial three-year period (e.g., suggestions on how to maintain research through commitment to sustain funds for consumables, etc., or efforts to obtain new and/or complementary funds).
- vi. Detailed budget with justification for each year of the project, including costs for training, equipment, consumables and travel. (Note: Equipment will be bought centrally by WIOMSA, and funding does not cover staff salaries but can go toward student assistants or casual labour).
- vii. Self-assessment: what is currently missing to establish/implement long-term marine litter monitoring or laboratory research (specific items to describe: expertise/training, and equipment needs detailed)..

c. Staffing capacity

- i. At least one senior person possessing a Masters degree in science or higher.
- ii. Proven ability to competently write project reports.

- iii. At least one technician.
- iv. At least one member of staff must be proficient in engaging and mobilizing public involvement.
- v. Attach CVs of staff to be involved in Appendix. Each CV should be a maximum of two pages in length and should include publications and relevant projects previously involved in.

3. Selection criteria include:

- a. Relevance and technical quality of the proposed research project including methods and merits of the selected study sites.
- b. Proximity or ease of access to study sites to facilitate regular field monitoring.
- c. Capacity to undertake and interpret research:
 - i. Exhibiting sufficient understanding of the marine litter problem and current global research into marine litter.
 - ii. Capacity to mobilize sufficient, appropriately qualified personnel to lead and undertake monitoring tasks over a three-year period, including: :
 - At least one senior person possessing a Masters degree in science or higher.
 - At least one technician.
 - At least one member of staff must be proficient in engaging and mobilizing public involvement.
 - iii. Personnel should have skills and qualifications necessary (or willingness to be trained) to undertake monitoring research. Proven ability would be required in:

- Research
- Scientific method
- Data collection, management and interpretation
- Strategic planning
- Teaching, education and awareness (including the ability to inspire the public and local communities)

The following skills are valuable:

- Numerical methods and statistics
 - GIS and mapping
 - Predictive modelling
 - Chemistry with a strength in water analysis, specifically for microplastics and their associated toxins and biofilms
- iv. The institutional infrastructure to properly conduct monitoring and research including but not limited to:
- Appropriate and adequate road transport and watercraft
 - Internet connectivity
 - Ready access to physical or online libraries

Additional beneficial infrastructure could include:

- Laboratory space and facilities (e.g. wet lab, storage for samples)
 - Appropriate equipment including microscopes and balances
- v. Solid track record of report writing and delivery on contractual obligations.
- vi. Plans and capacity to maintain monitoring programs beyond initial three-year period. Such plans might include a fund-raising strategy if additional funds are necessary.
- d. Realistic budget.
- e. Potential for collaboration and partnerships with other institutions in the region and internationally.
- f. Ability and plans to involve local education and awareness initiatives in the monitoring program.

6. Capacity building strategy

If Africa is to succeed in meeting the challenges to win the battle against litter, we need to build capacity. The negative impacts of litter accumulation on the society, economy, health and environment must be better understood by all. Therefore, promoting skills transfer, refining educational curricula and creating effective public awareness campaigns are prerequisites to successful litter mitigation.

In addition to formal education programmes, there is a need to develop the best methods to raise awareness and understanding while promoting public participation; to develop local, regional (in this case the WIO region) and continent-wide communications packages; to establish and promote an ethic of responsible consumer behaviour as well as sustainable litter management and legitimate concern for the state of the environment.

6.1 Aims, Objectives and Expected Outcomes

The capacity building strategy aims to provide a framework for content knowledge development, skills transfer, equipment development and infrastructural capacity development, particularly for the purposes of enabling institutions to undertake litter monitoring in the WIO region.

6.1.1 Content knowledge

It is necessary to provide all participating institutions with a comprehensive overview of the basic concepts of marine litter. Thus, training and information-sharing will be conducted during planned training sessions on marine litter (e.g., definition, types, and chemical composition), environmental impacts of marine litter (e.g., the risks of

entanglement in and ingestion of litter by living organisms, leaching of harmful chemicals, bioaccumulation), the potential impacts of marine litter on human health (e.g., endocrine inhibition and cancers) and impacts of marine litter on the economy (e.g., disruption of ecosystem services, loss of natural resources including fisheries, loss of tourism revenue). It is proposed that local African experts are to lead these training sessions and, where possible, international experts are to join in person or via webinar.

The outcome is an extensive knowledge base of marine litter within the participating institution teams, including their project leaders, technicians and students.

6.1.2 Skills transfer

In order to facilitate skills transfer, practical training sessions on the monitoring protocols for beach and rocky shore, river and estuary, and point source monitoring, will be held.

There will be a strong focus on experiential learning (i.e., learning through experience and reflecting on that experience) during these sessions, with the expected outcome of strong skills development of consistent, accurate and precise sample collection, data capture and basic data processing, within each institution team member.

6.1.3. Infrastructural capacity

Infrastructural capacity will be built through the development of a network between participating institutions, introduced during the initial training phase (Stage 1 training). This network will enable knowledge and skills of Stage 1 training to be shared throughout the institutions during an extended monitoring period. This will be facilitated through the provision of training resources that can also be used during future training sessions (Stage 2 training), to continue a chain of education and capacity building throughout the participating institutions and potentially to others in the future.

6.2 Stage 1 Training

In order to achieve the objectives outlined above, an initial intense five day training programme is proposed. It is essential that all members of the monitoring team attend this first stage of an institution's monitoring programme, which will be guided by the information outlined in this document and in the "Manual for Marine Litter Monitoring" that has been categorized into 13 training modules (e.g., How to identify and categorize litter). It is recommended that a hard copy or electronic copy of the "Manual for Marine Litter Monitoring" be provided during the training sessions to the trainers and trainees.

All institutions and their team members who complete Stage 1 training could be awarded an accredited certificate (e.g., by WIOMSA).

6.2.1 Module training plans

The following module plans can be used by trainers to guide their sessions.

1. TOPIC: Module 1: Introduction to marine litter

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 120 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Provide a comprehensive definition of marine litter, identify and categorize its different components and have an understanding of the marine litter crisis globally and in Africa.
2. Understand the composition of marine litter (predominantly plastic and its harmful polymers and additives).
3. Understand the waste cycle, including microplastics and how they are manufactured or derived.

Introduction:

Training begins with the definitions of marine litter and the categories thereof (according to size: nano to macro). Imagery of the marine litter crises globally and in Africa will be shown, accompanied by statistics obtained from the latest scientific reports/articles.

Training progression phase:

Training progresses with the basic chemical compositions of marine litter, highlighting the harmful polymers and additives, which pose environmental and human health threats. Thereafter trainers and trainees delve into the waste cycle from raw materials, production, distribution, consumption to recycling or disposal. This will incorporate primary and secondary microplastics, with industrial and household examples. Case studies of marine litter hot spots should be provided (e.g., Mumbai, India).

Conclusion:

The training session concludes with a Q and A and discussion session. A written assessment can be provided to all trainees to complete, whereby their existing knowledge on these topics is assessed.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees. Trainees will also gain insight into understanding through the completed written assessments.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board.

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities.

2. TOPIC: Module 2: Impacts of marine litter on the environment

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 60 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

Understand and report on the impacts of marine litter on the environment, which include: ingestion and entanglement and other physical harm incurred by terrestrial and aquatic organisms, smothering of aquatic environments (freshwater, estuarine and marine), transport and facilitation of invasive alien species, as well as the impacts of microplastics, from ingestion to leaching into tissues (bioaccumulation up trophic levels, which includes humans) and the aquatic environment (e.g., water contamination).

Introduction:

The training begins with an overview of marine litter in the environment, accompanied by a series of images and videos. Based on these images, trainees will be prompted to discuss and report verbally the potential environmental impacts seen in the images and videos.

Training progression phase:

The training progresses with detailed outlines of:

- Ingestion and entanglement and other physical harm incurred by terrestrial and aquatic organisms, and the consequences thereof (e.g., immediate consequence: organism death; prolonged consequence: biodiversity loss due to ecosystem collapse), accompanied by statistics if available. Case studies on existing examples of these processes should be included.
- Smothering of aquatic environments (freshwater, estuarine and marine) and the consequences thereof (e.g., immediate: organism death; prolonged: biodiversity loss due to ecosystem collapse) accompanied by statistics if available. Case studies on existing examples of these processes should be included. Particular focus should be on highly productive ecosystems including coral reefs, mangroves, salt marshes etc.
- Transport and facilitation of invasive alien species through movement of marine litter over great distances, carried by wind and water, and the consequences thereof. This should be accompanied by statistics and case studies if available.
- The impacts of microplastics, from ingestion to leaching into tissues (including a description of the bioaccumulation process) and the aquatic environment (e.g., water contamination). This will include the acute and chronic impacts on animal and ecosystem health (the lack of definitive data in this

regard must be noted). Not only the inherent toxic nature of microplastic polymers and additives, but the absorption and adsorption of harmful chemicals already existing in the water column into the microplastics during prolonged suspension, must also be highlighted. This should be accompanied by statistics and case studies if available.

Conclusion:

The training session concludes with a Q and A and discussion session. A written assessment can be provided to all trainees to complete, whereby their existing knowledge on these topics is assessed.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the introduction discussion and reporting phase, as well as during the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board.

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities.

3 TOPIC: Module 3: Impacts of marine litter on human health

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 60 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Understand what Persistent Organic Pollutants (POPs) are and their impact on human health through ingestion.
2. Understand the physical harm and spread of disease caused by litter.

Introduction:

The training begins with an overview of POPs, including those of current key concern: polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons, petroleum hydrocarbons, organochlorine pesticides (including DDT and its metabolites), hexachlorinated hexane (HCH), polybrominated diphenylethers (PBDEs), alkylphenols and Bisphenol A (BPA). This overview will include the purpose of these compounds in the plastic manufacturing process (i.e., polymers, stabilizers, flame retardants etc.) or if they are secondarily absorbed by plastics while suspended in the water column.

Training progression phase:

The training progresses with an outline of the suspected human health impacts; the consumption or exposure to POPs will be highlighted. These include endocrine disruption, cancers, skin irritations, organ damage etc. This should be accompanied by statistics and case studies if available.

The physical harm caused by litter (e.g., cuts, abrasions and spreading of disease) and how accumulated litter can facilitate the spread of disease (e.g., cholera and malaria by trapping stagnant water) will also be described.

It must be noted during this portion of the session that data and research providing direct links to microplastics and these human health issues are lacking, therefore highlighting an important opportunity to fill in these gaps with microplastics monitoring and research.

Conclusion:

The training session concludes with a Q and A and discussion session. A written assessment can be provided to all trainees to complete, whereby their existing knowledge on these topics is assessed.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees. Trainees will also gain insight into understanding through the completed written assessments.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities.

4. TOPIC: Module 4: Impacts of marine litter on the economy

- **TRAINERS:** SST education team/WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 60 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Understand the connection between biodiversity loss and ecosystem collapse with the breakdown of ecosystem services valuable to the economy (directly or indirectly).
2. Understand the repercussions of marine litter on the tourism, recreation and fishing industries, together with the impact of alien invasive species on these industries and the above mentioned biodiversity and ecosystem services.

Introduction:

The training begins with trainees being prompted to discuss and report verbally the potential economic impacts of marine litter as seen in previous images and videos.

Training progression phase:

The training progresses with a detailed outline of the following:

- Biodiversity and ecosystem services directly impacted by marine litter, which are quantifiable in terms of monetary value (e.g., fish stocks). Those which are incalculable in terms of monetary value at present (e.g., nutrient cycling and water purification) should then be highlighted.

- The impacts of marine litter on tourism and recreation and the costs of conducting large scale clean ups.
- The costs of marine litter to the fishing industry including lost gear, damage to fishing vessels, damage to fisheries stocks and the cost of large scale clean ups.
- The costs relating to eradication of alien invasive species and the economic losses linked to ecosystem degradation and loss of resources resulting from alien invasive species.

This information should be supported by statistics and case studies if available..

Conclusion:

The training session concludes with a Q and A and discussion session. A written assessment can be provided to all trainees to complete, whereby their existing knowledge on these topics is assessed..

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees. Trainees will also gain insight into understanding through the completed written assessments.

Resources:

Technology –laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities.

5. TOPIC: Module 5: A theoretical guide to beach and rocky shore surveying

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 180 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Understand and identify the factors that influence litter deposition.
2. Understand the theory behind accumulation, standing stock and synoptic surveys.
3. Know how to sample and process macro, meso and micro litter on a beach or rocky shore.
4. Understand how to complete a sampling site selection and description.

Introduction:

Training begins with an outline of the entire sampling process of a beach and rocky shore survey and the factors that influence litter deposition including local and offshore currents, slope, aspect, length, tidal range and prevailing wind.

Training progression phase:

The training progresses with detailed descriptions of each component of the sampling process:

- Accumulation surveys including illustrations of sampling layout (i.e., demarcated sampling areas: Appendix 5) and pros and cons.
- Standing stock surveys pros and cons.
- Synoptic surveys, their applicability in terms of location and their pros and cons.
- Methods used to sample macro (accumulation surveys), meso (accumulation surveys) and micro litter (seawater sampling and optional sediment sampling protocols).
- Methods used to process micro litter samples (i.e., sieving, filtration, using a Sediment-Microplastic Isolation (SMI) unit and visual sorting with microscopy: dissecting, spectral and fluorescent) and avoiding contamination in the field.
- Sampling site selection (i.e., specified criteria as proposed in Chapter 4) and description, including a step by step guide on completing a shoreline categorization sheet (Appendix 4)..

Conclusion:

The training session concludes with a Q and A and discussion session.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees.

Resources:

Technology –laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board and demo sampling equipment (if needed; the SST education team has/will have these resources available)

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities. Practical aspects of training may need to be led in person with demonstrations.

6. TOPIC: Module 6: A practical guide to beach and rocky shore surveying

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 180 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Select an appropriate sampling site and record sampling site information.

2. Practise macro, meso and micro litter surveys on a beach or rocky shore anywhere across the Western Indian Ocean countries.
3. Complete data recording for these surveys.

Introduction:

The training begins with each team being tasked to select an appropriate site for sampling within the chosen practical site (i.e., a beach or rocky shore close to the training lecture hall or conference room). Trainers will be available to provide guidance during site selection. Then once selected the teams will need to complete a site description (Appendix 4).

Training progression phase:

The training progresses with each team carrying out the following sampling process within the chosen sampling site:

- Macro litter accumulation survey obtaining macro litter weight values (within a demarcated area) and data recording using a medium resolution data sheet (Appendix 3).
- Meso litter accumulation survey including sieving (along strand line transects) and data recording using a medium resolution data sheet (Appendix 3).
- Micro litter surveys including preventing contamination, sea water sample collection and optional sediment sample collection protocols.

Optional training will provide the team with a broader skills base, wherein they are able to make an informed decision on the most appropriate method to use in their own monitoring programmes.

Conclusion:

Each team will provide feedback on the methods used and on which methods are likely to be most suitable for their chosen monitoring sites..

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the course of the practical, with trainees observing the practices of each team and providing guidance where needed.

Resources:

Technology – no technology is required

Content resources – Training manual, note pads and data sheets

Training/practical resources – Sampling equipment including handheld GPS (cell phones can be used as an alternative), work gloves, refuse bags, demarcation flags, measuring tape, Newton scale, paint, sieves, buckets, glass jars and ethanol, tweezers, (Petri dishes, quadrats, metal spoon, concentrated NaCl solution, filter paper, Büchner funnel, large test tubes with stoppers, separating funnel, distilled water, oven, parafilm and a dissecting microscope are optional for sampling and processing protocols).

Training location:

WIOMSA selected rocky shore or beach reasonably close to the training lecture hall or conference room..

7. TOPIC: Module 7: A theoretical guide to river and estuary surveying

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 180 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

Understand and identify the factors which effect litter transport in rivers and estuaries, how to sample macro, meso and micro litter within the water column, how to sample macro, meso and micro litter on river and estuary banks and understand how to complete the sampling site selection and description.

Introduction:

The training begins with an outline of the entire sampling process of a river and/or estuary survey and factors that influence litter transport in rivers and estuaries (e.g., hydrology and morphology).

Training progression phase:

The training progresses with detailed descriptions of each component of the sampling process:

- Macro, meso and micro litter within the water column using trawl nets to determine trash load of rivers/ estuaries. This includes an explanation of the appropriate equations and flow measurements (using a flow meter or the orange peel method).

- Macro, meso and micro litter on the river/estuary banks using surveys demonstrated in training plans 5 and 6.
- Recycled trawl alternatives.
- Sampling site selection (i.e., specified criteria as proposed in Chapter 4) and description.
- Additional macro litter monitoring in mangroves using surveys demonstrated in training plans 5 and 6

Conclusion:

The training session concludes with a Q and A and discussion session.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board and demo sampling equipment (if needed; the SST education team has /will have these resources available)

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities. Practical aspects of training may need to be led in person with demonstrations.

8. TOPIC: Module 8: A practical guide to river and estuary surveying

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 180 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Select an appropriate sampling site and record sampling site information.
2. Practise macro, meso and micro litter surveying within the water column and on the banks of rivers and estuaries anywhere across the Western Indian Ocean countries.
3. Complete data recording for these surveys.

Introduction:

The training begins with each team being tasked to select an appropriate site for sampling within the chosen practical site (i.e., a river or estuary close to the training lecture hall or conference room). Trainers will be available to provide guidance during site selection. Then, once selected, the teams will need to complete a site description (Appendix 4).

Training progression phase:

The training progresses with detailed descriptions of each component of the sampling process:

- Macro, meso and micro litter within the water column using trawl nets as described and demonstrated in training plans 7 and 9.

- Macro, meso and micro litter surveys at land-based point sources using surveys as described and demonstrated in training plans 5 and 6.
- Sampling site selection (i.e., specified criteria as proposed in Chapter 4, including permits) and description.

Conclusion:

Each team will provide feedback on the methods used and which methods are likely to be most suitable for their chosen monitoring sites.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the course of the practical, with trainees observing the practices of each team and providing guidance where needed.

Resources:

Technology – no technology is required

Content resources – Training manual, note pads and data sheets

Training resources – Sampling equipment including a rectangular trawl, macro and neuston net, stabilizing line, flow meter or “orange peel,” stopwatch, traffic cone, handheld GPS (cell phones can be used as an alternative), work gloves, refuse bags, demarcation flags, measuring tape, Newton scale, paint, sieves, buckets, glass jars and ethanol, tweezers (Petri dishes, quadrats, metal spoon, concentrated NaCl solution, filter paper, Büchner funnel, large test tubes with stoppers, separating funnel, distilled water, oven, parafilm and a dissecting microscope for optional sampling and processing protocols).

Training location:

WIOMSA selected river or estuary (mangrove if possible) reasonably close to the training lecture hall or conference room.

9. TOPIC: Module 9: A theoretical guide to point source surveying

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 180 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Sample point source litter in water.
2. Sample point source litter on land.
3. Complete the sampling site selection and description.

Introduction:

The training begins with an outline of the entire sampling process of point sources (this includes providing visual examples of point sources).

Training progression phase:

The training progresses with detailed descriptions of each component of the sampling process::

- Macro, meso and micro litter within the water column using trawl nets as described and demonstrated in training plans 7 and 9.
- Macro, meso and micro litter surveys at land-based point sources using surveys as described and demonstrated in training plans 5 and 6.

- Sampling site selection (i.e., specified criteria as proposed in Chapter 4, including permits) and description

Conclusion:

The training session concludes with a Q and A and discussion session.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board and demo sampling equipment (if needed; the SST education team has /will have these resources available)

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact.

Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities. Practical aspects of training may need to be led in person with demonstrations.

10. TOPIC: Module 10: A practical guide to point source surveying

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 180 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Select an appropriate sampling site and record sampling site information.
2. Practice macro, meso and micro litter point source surveys in water using trawls and on land using accumulation surveys anywhere across the Western Indian Ocean countries.
3. Complete data recording for these surveys.

Introduction:

The training begins with all trainees being tasked to select an appropriate site for sampling within the chosen practical site (i.e., point source in water and on land). If there are multiple point sources in close proximity to each other, the trainees can be divided to work within smaller teams. Trainers will be available to provide guidance during site selection. Then once selected the teams will need to complete a site description (Appendix 4).

Training progression phase:

The training progresses with each team carrying out the following sampling process within the chosen sampling site:

- Macro, meso and micro litter within the water column using trawl nets as described and demonstrated in training plans 7 and 9.
- Macro, meso and micro litter surveys at land-based point sources using surveys as described and demonstrated in training plans 5 and 6.

Conclusion:

Each team will provide feedback on the methods used and which methods are likely to be most suitable for their chosen monitoring sites.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the course of the practical, with trainees observing the practices of each team and providing guidance where needed.

Resources:

Technology – No technology is required

Content resources – Training manual, note pads and data sheets

Training resources – Sampling equipment including a rectangular trawl, macro and neuston net, stabilizing line, flow meter or “orange peel,” stopwatch, traffic cone, handheld GPS (cell phones can be used as an alternative), work gloves, refuse bags, demarcation flags, measuring tape, Newton scale, paint, sieves, buckets, glass jars and ethanol, tweezers, (Petri dishes, quadrats, metal spoon, concentrated NaCl solution, filter paper, Büchner funnel, large test tubes with stoppers, separating funnel, distilled water, oven, parafilm and a dissecting microscope for

optional sampling and processing protocols.)

Training location:

WIOMSA selected point source in water and/or on land reasonably close to the training lecture hall or conference room.

11 TOPIC: Module 11: Data capture consistency

- **TRAINERS:** SST education team/ WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 60 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Understand the different methods used to quantify litter.
2. Develop an appropriate survey schedule.
3. Control sampling effort to avoid bias.

Introduction:

The training begins with trainees being prompted to examine their datasheets and reflect on the previous day's practical sessions in terms of consistency in data capture. They will then be encouraged to suggest methods to ensure data capture consistency across all surveying techniques.

Training progression phase:

The training progresses with detailed descriptions of the different methods used to quantify litter (presence/absence, counts, weights and volumes) and how to develop an appropriate survey schedule that would incorporate seasonal changes in rainfall and wind. Additionally, how to control sampling effort (number of people surveying litter at a given site, at a given time) to avoid bias will

be outlined (e.g., keeping team members and surveyors constant over time).

Conclusion:

The training session concludes with a Q and A and discussion session.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during introduction report backs from teams and the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board (if needed; the SST education team has /will have these resources available)

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities.

12 TOPIC: Module 12: Data handling consistency

- **TRAINERS:** SST education team/WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 60 minutes

Outcomes: *By the end of this training session, trainees will be able to:*

1. Understand the need for centralized data storage.
2. Understand qualitative and quantitative assessment of data.

Introduction:

The training begins with demonstration of a centralized data storage system format as prescribed by WIOMSA. This includes data uniformity, collection, storage and distribution requirements.

Training progression phase:

The training progresses with detailed descriptions of qualitative (representativeness and comparability) and quantitative assessment of data (completeness, precision, accuracy).

Conclusion:

The training session concludes with a Q and A and discussion session.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during introduction data recording and the question and answer and discussion session at the end of the training session. Additionally, questions and discussion during the course of the session will be encouraged and will be addressed by the trainers or fellow trainees.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, scientific reports and articles, note pads

Training resources – White board (if needed; the SST education team has /will have these resources available)

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training can be accomplished remotely using webinar facilities.

13. TOPIC: Module 13: A practical guide to microplastic sample processing

- **TRAINERS:** SST education team/WIOMSA education team/experts from Africa and other continents
- **TRAINEES:** Marine litter observation system project leaders, technicians and students
- **DURATION:** 180 minutes

Outcomes: *By the end of this training session, trainees will be able to;*

1. Avoid contamination of microplastic samples in the laboratory.
2. Process sea water samples.
3. Process sediment samples.
4. Identify and quantify microplastics using microscopy.

Introduction:

The training begins with the essential steps which need to be taken to avoid contamination of samples (sea water or sediment), including storage of samples, work space specifications, lab equipment preparation and preparation of control samples.

Training progression phase:

The training progresses with each team carrying out the following sample processing within a lab:

- Sea water sample processing which includes sieving and microscope work.

- Sediment sample processing which includes oven drying, filtration, sieving and microscope work.
- Sediment sample processing using density separation through a Sediment-Microplastics Isolation (SMI) unit.
- Identification of microplastics under the microscope.
- Identification of microplastics under a fluorescent microscope using Nile Red.

Conclusion:

Each team will provide feedback on the methods used and which methods are likely to be most suitable for their institutions and available capacity.

Assessment of understanding tools:

Assessment of trainee understanding will be determined during the course of the practical, with trainees observing the practices of each team and providing guidance where needed.

Resources:

Technology – laptop, overhead projector, Power Point, video and digital imagery

Content resources – Training manual, note pads and data sheets

Training resources – dissecting microscope or stereoscope, 70% filtered ethanol, Petri dishes, parafilm, tweezers, NaCl, graduated sieves, metal spoon, filtered water, 70% filtered ethanol, filter paper, Sediment-Microplastics Isolation (SMI) unit, Nile Red, fluorescent microscope.

Training location:

WIOMSA selected lab in which trainers and trainees can interact. If no lab space is available, a temporary lab can be set up in a large hall or room.

6.2.2.Trainer and trainee reflection

Given the different contexts and backgrounds of the institutions and their teams, it is difficult to know the receptiveness of the participants to the information and the training methods. Therefore, it is imperative for long term, sustainable capacity building, that the trainers and trainees reflect on the training sessions, in order for the training programme to be adapted where necessary for improved knowledge development and

skills transfer. The following questions are proposed as part of reflection:

1. To what extent were the intended lesson outcomes achieved?
2. What should be changed if this training session were to be presented again?
3. To what extent were participants actively engaged in the training session?
4. How can we build on what has been learnt in this training session?
5. Other ideas for grouping and methodology.

1	Introduction to marine litter	What is marine litter	How to identify and categorise litter	Chemical composition of plastics	Microplastics
2	Impacts of marine litter on the environment	Ingestion and entanglement	Smothering of aquatic ecosystems	Marine litter and Invasive species	Microplastics and Bioaccumulation
3	Impacts of marine litter on human health	Persistent Organic Pollutants (POPs)	Microplastics and Bioaccumulation		
4	Impacts of marine litter on the economy	Ecosystem services	Tourism and recreation	Fishing industry (ALDFG)	Invasive species
5	A theoretical guide to beach and rocky shore surveying	Factors affecting litter deposition	Standing-stock and Accumulation surveys	Microplastics	Site selection and description
6	A practical guide to beach and rocky shore surveying	In field site selection and description	In field Standing-stock and Accumulation surveys	In field microplastics surveys	Data recording
7	A theoretical guide to river and estuary surveying	Factors affecting transport litter transport	Surveying macro, meso and micro litter in the water column	Surveying macro, meso and micro litter on banks	Site selection and description
8	A practical guide to river and estuary surveying	In field site selection and description	In field surveying macro, meso and micro litter in the water column	In field surveying macro, meso and micro litter on banks	Data recording
9	A theoretical guide to point source surveying	Monitoring point source in water	Monitoring point source on land	Site selection and description	
10	A practical guide to point source surveying	In field site selection and description	Monitoring point source in water	Monitoring point source on land	
11	Sampling and Data capture consistency	Quantifying litter	Monitoring time frames	Sampling effort	
12	Data handling consistency	Centralised data storage	representiveness and comparability	completeness, precision and accuracy	
13	A practical guide to equipment sourcing and construction	Equipment lists	constructing a weighted manta trawl and recycled trawl	Flow meters and orange peel method	Constructing floating booms, collection grids and "Bandalong" litter boom

Figure 10: Module break down of the training programme

Table 7: Intensive Five day work plan for Stage 1 training

Time	Day 1	Day 2	Day 3	Day 4	Day 5
8:00 – 8:30	Module 1: Introduction to marine litter	Module 5: A theoretical guide to beach and rocky shore surveying	Module 7: A theoretical guide to river and estuary surveying	Module 9: A theoretical guide to point source surveying	Module 11: Data capture consistency
8:30 – 9:00					
9:00 – 9:30					
9:30 – 10:00					
10:00 – 10:30	Tea Break	Tea Break	Tea Break	Tea Break	Module 12: Data handling consistency
10:30 – 11:00	Module 2: Impacts of marine litter on the environment	Module 5: A theoretical guide to beach and rocky shore surveying	Module 7: A theoretical guide to river and estuary surveying	Module 9: A theoretical guide to point source surveying	Tea Break
11:00 – 11:30					
11:30 – 12:00					
12:00 – 12:30	Module 3: Impacts of marine litter on human health	Lunch	Lunch	Lunch	Module 13: A practical guide to equipment sourcing and construction
12:30 – 13:00					
13:00 – 13:30	Lunch	Module 6: A practical guide to beach and rocky shore surveying	Module 8: A practical guide to river and estuary surveying	Module 10: A practical guide to point source surveying	Lunch
13:30 – 14:00					
14:00 – 14:30					
14:30 – 15:00	Module 4: Impacts of marine litter on the economy	Module 6: A practical guide to beach and rocky shore surveying	Module 8: A practical guide to river and estuary surveying	Module 10: A practical guide to point source surveying	Module 13: A practical guide to equipment sourcing and construction
15:00 – 15:30					
15:30 – 16:00					
16:00 – 16:30	Concluding remarks and brief for the following days				Concluding remarks to training programme
16:30 – 17:00					

6.3 Stage 2 Training

In order to ensure sustainable capacity building in the long term, a second phase of training is proposed (Stage 2 training). This will include training sessions and assessments conducted every year following the initial training, serving as refreshers to the institutions of the marine litter observation system. This may also include training sessions for citizen volunteers to assist in the marine litter observation system, which may need to be conducted more frequently depending on institution needs. Furthermore, this phase of training can extend to new institutions joining the marine litter observation system.

6.3.1 Training plan

TOPIC: Modules 1 to 13.

TRAINERS: SST education team/WIOMSA education team/Marine litter observation system institution /experts from Africa and other continents.

TRAINEES: Marine litter observation system project leaders, technicians, students, volunteers or new institutions.

DURATION: Refresher training and assessment (1 day) or volunteer and new institution training (5 days).

Outcomes:

Institution refresher training – ensure understanding of the content and possession of the skills outlined in Modules 1 to 13.

Volunteer and new institution training – develop understanding of content knowledge and skills outlined in Modules 1 to 13. These courses will follow Stage 1 module training plans.

Assessment of understanding tools:

Institution refresher training – a formal written and practical assessment can be completed by teams, with a minimum score requirement to receive a renewal of their Stage 1 certificate. If this minimum score is not met, then the team will need to complete the full Stage 1 training programme again. It must be noted that it is imperative to maintain a high standard of monitoring through key content knowledge and skills maintenance. However, the objectives of these assessments are not to penalize institutions.

Volunteer and new institution training - trainee understanding will be determined during the course of the 5 day training programme as outlined in the Stage 1 module training plans.

Resources:

Institution refresher training

Institution refresher training

Technology – no technology is required, however the written and practical assessments can be based online with available infrastructure (e.g., the African Waste Academy).

Assessment resources – an alternative to online assessments are hard copy assessment sheets.

Volunteer and new institution training
Technology, content resources and training resources – outlined in Stage 1 module training plans.

Volunteer and new institution training
Technology, content resources and training resources – outlined in Stage 1 module training plans.

Training location:

WIOMSA selected lecture hall or conference room in which trainers and trainees can interact. Alternatively, the theoretical aspects of training

can be accomplished remotely using webinar facilities. Practical aspects of training may need to be led in person with demonstrations.

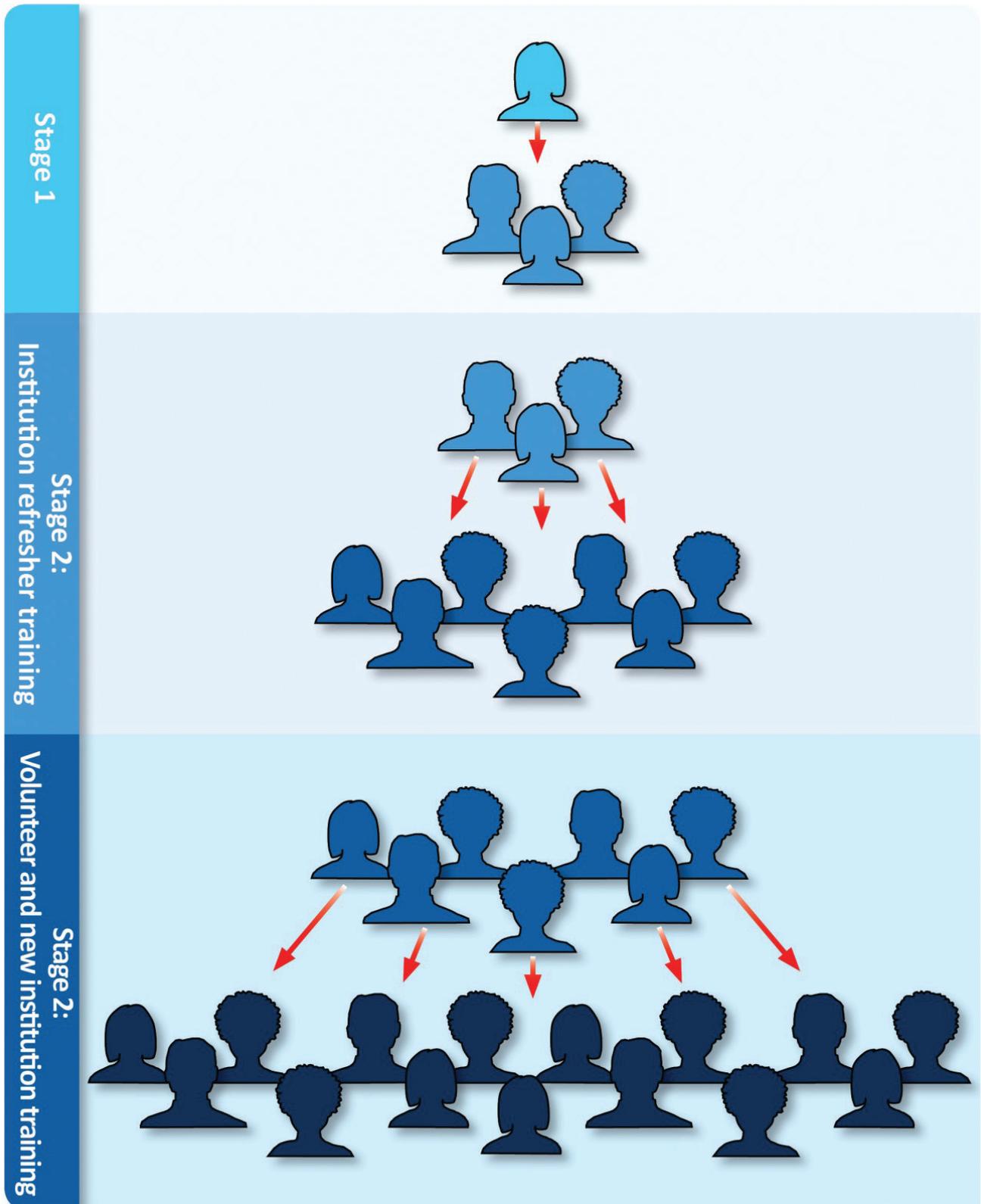


Figure 8: Expected knowledge, skills and equipment transfer over the long term implementation of the training programme

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Appendices

Appendix 1: Abbreviations

#	number
ALDFG	abandoned, lost or discarded fishing gear
AMWN	African Marine Litter Network
EU	European Union
gal	gallons
GIS	Geographic Information Systems
IUU	illegal, unreported and unregulated
m	meter(s)
NOAA	National Ocean and Atmospheric Association
POPs	persistent organic pollutants
sec	second
SST	Sustainable Seas Trust
UNEP	United Nations Environmental Program
US\$	United States dollar
WIO	Western Indian Ocean
WIOMSA	Western Indian Ocean Marine Science Association

Appendix 2: Definitions

baseline	a minimum or starting point used for comparisons
bioaccumulation	the accumulation of a substance, such as a toxic chemical, in various tissues of a living organism
biomagnify	the increasing concentration of a substance, such as a toxic chemical, in the tissues of organisms at successively higher levels in a food chain
biota	the animal and plant life of a particular region, habitat, or geological period
benthic	on the sea-bed
GIS	a geographic information system (GIS) is a system designed to capture, store, manipulate, analyse, manage, and present spatial or geographic data
ghost gear	any fishing equipment or fishing-related litter that has been abandoned, lost or otherwise discarded
flow meter	an instrument used to measure linear, nonlinear, volumetric or mass flow rate of a liquid or a gas
litter flux	litter quantities transported by rivers per unit time
macroplastic	plastic larger than 25mm in diameter
marine litter	persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment
mesoplastic	plastic between 5 and 25mm in diameter
microfiber	a synthetic fibre with a diameter less than 10 micrometers
microplastics	small particles or fragments of plastic smaller than 5mm in diameter
nurdle	a very small pellet of plastic which serves as raw material in the manufacture of plastic products
supernatant	the liquid lying above a solid residue after crystallization, precipitation, centrifugation, or other process
watershed	an area or ridge of land that separates waters flowing to different rivers, basins, or seas

Appendix 3: Example of medium resolution data collection sheet

Source: NOAA (Opfer, Arthur and Lippiatt, 2012)

<p>SHORELINE DEBRIS Debris Density Data Sheet</p> <p>Complete this form during EACH survey or transect (if standing-stock) per site visit</p>	Organization		Name of organization responsible for data collection
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
	Surveyor name		Email contact for surveyor
	Date		Date of this survey

ADDITIONAL INFORMATION

Shoreline name	Accumulation <input type="checkbox"/>	Standing-stock <input type="checkbox"/>	Name of section of shoreline (e.g., beach name, park)
Survey Type			Type of shoreline survey conducted (check box)
Transect ID # (N/A if accumulation survey)	Latitude	Longitude	Transect ID (include shoreline ID, date, and transect #)
Coordinates of start of shoreline site		Recorded as XXX.XXXX (decimal degrees). Record in both corners if width >6 m. If transect, record at water's edge.
Coordinates of end of shoreline site	Latitude	Longitude	Recorded as XXX.XXXX (decimal degrees). Record in both corners if width >6 m. If transect, record at back of shoreline.
Width of beach			Width of beach at time of shoreline. Width of beach at time of survey from water's edge to back of shoreline (metres).
Time start/end	Start	End	Time at the beginning and end of the survey
Season			Spring, summer, fall, winter, tropical wet, etc.
Date of last survey			Date on which the last survey was conducted
Storm activity			Describe significant storm activity within the previous week (date(s), high winds, etc.)
Current weather			Describe weather on sampling day, including wind speed and % cloud coverage
Number of persons			Number of persons conducting the survey
Large items	YES	NO	Did you note large items in the large debris section?
Photo ID#s			The digital identification number(s) of debris photos taken during the survey

Notes: Evidence of cleanup, sampling issues, etc.

DEBRIS DATA: (continued on the back)				
ITEM	TALLY (e.g. IIII)			TOTAL
PLASTIC				
Plastic fragments	Hard	Foamed	Film	
Food wrappers				
Beverage bottles				
Other jugs or containers				
Bottle or container caps				
Cigar tips				
Cigarettes				
Disposable cigarette lighters				
6-pack rings				
Bags				
Plastic ropes/small net pieces				
Bouys & floats				
Fishing lures and lines				
Cups (including polystyrene/foamed plastic)				
Plastic utensils				
Straws				
Balloons				
Personal care products				
Other:				
METAL				
Aluminium/tin cans				
Aerosol cans				
Metal fragments				
Other:				
GLASS				
Beverage Bottles				
Jugs				
Glass fragments				
Others:				

ITEM	TALLY (e.g. IIII)			TOTAL
RUBBER				
Flip-flops				
Gloves				
Tyres				
Rubber fragments				
Other				
PROCESSED LUMBER				
Cardboard cartons				
Paper bags				
Lumber/building materials				
Other:				
CLOTH/FABRIC				
Clothing & shoes				
Gloves (non-rubber)				
Towels/rugs				
Rope/net pieces (non-nylon)				
Fabric pieces				
Other:				
OTHER/UNCLASSIFIABLE				
LARGE DEBRIS ITEMS (>1 foot or ~ 0.3 m)				
Item types (vessels, nets, etc.)	Status (sunken, stranded, buried)	Approximate width (m)	Approximate length (m)	Description/photo ID#
Notes on debris items, description of "Other /unclassifiable" items, etc.				

Appendix 4: Example of shoreline characterisation sheet

Source: NOAA (Opfer, Arthur and Lippiatt, 2012)

<p>SHORELINE DEBRIS Shoreline Characterization Sheet</p> <p>Complete this form during ONCE for each site location</p>	Organization		Name of organization responsible for data collection
	Surveyor name		Name of person responsible for filling in this sheet
	Phone number		Phone contact for surveyor
	Surveyor name		Email contact for surveyor
	Date		Date of this survey

SAMPLING AREA

Shoreline ID		Unique code for shoreline
Shoreline name		Name by which the section of shoreline is known (e.g., beach name, park)
State/County		State or County where your site is located
Coordinates of end of shoreline section	Latitude Longitude	Recorded as XXX.XXXX (decimal degrees) at the start of shoreline section (in both corners of width >6 metres)
Coordinates of end of shoreline section	Latitude Longitude	Recorded as XXX.XXXX (decimal degrees) at the end of shoreline section (in both corners of width >6 metres)
Photo ID#		The digital identification number(s) of photos taken of shoreline section

SHORELINE CHARACTERISTICS - from beginning of shoreline site

Length of sample area (should be 100 m if standing-stock survey)		Length measured along the midpoint of the shoreline (in metres)
Substratum type		For example, a sandy or gravel beach
Substrate uniformity		Percent coverage of the main substrate type (%)
Tidal range		Maximum & minimum vertical tidal range. Use tide chart (usually in feet).
Tidal distance		Horizontal distance (in metres) from low- to high-tide line. Measure on the beach at low and high tides or estimate based on wrack lines.
Back of shoreline		Describe landward limit (e.g., vegetation, rock wall, cliff, dunes, parking lot).
Aspect		Direction you are facing when you look out at the water (e.g., northeast).

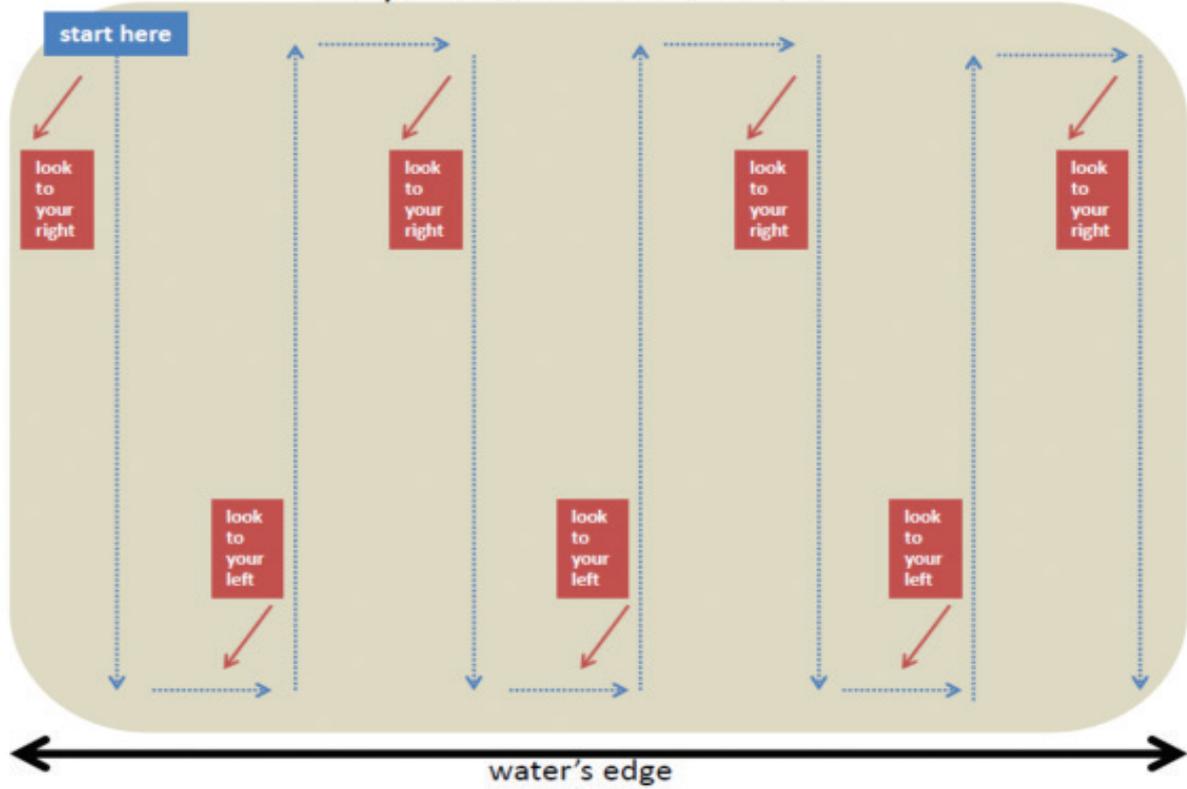
LAND-USE CHARACTERISTICS - within shoreline location

Location & major usage	Urban		Select one and indicate major usage (e.g., recreation, boat access, remote)
	Suburban		
	Rural		
Access			Vehicular (you can drive to your site), pedestrian (must walk), isolated (need a boat or plane)
Nearest town			Name of nearest town
Nearest town distance			Distance to nearest town (miles)
Nearest town direction			Direction to nearest town (cardinal direction)
Nearest river name			If applicable, name of nearest river or stream. If blank, assumed to mean no inputs nearby.
Nearest river distance			Distance to nearest river/ stream (km)
Nearest river direction			Direction to nearest river/ stream (cardinal direction from site)
River/creek input to beach	YES	NO	Whether nearest river/stream has an outlet within this shoreline section
Pipe or drain input	YES	NO	If there was a storm drain or channelized outlet within shoreline section
Notes (including description, landmarks, fishing activity, etc.):			

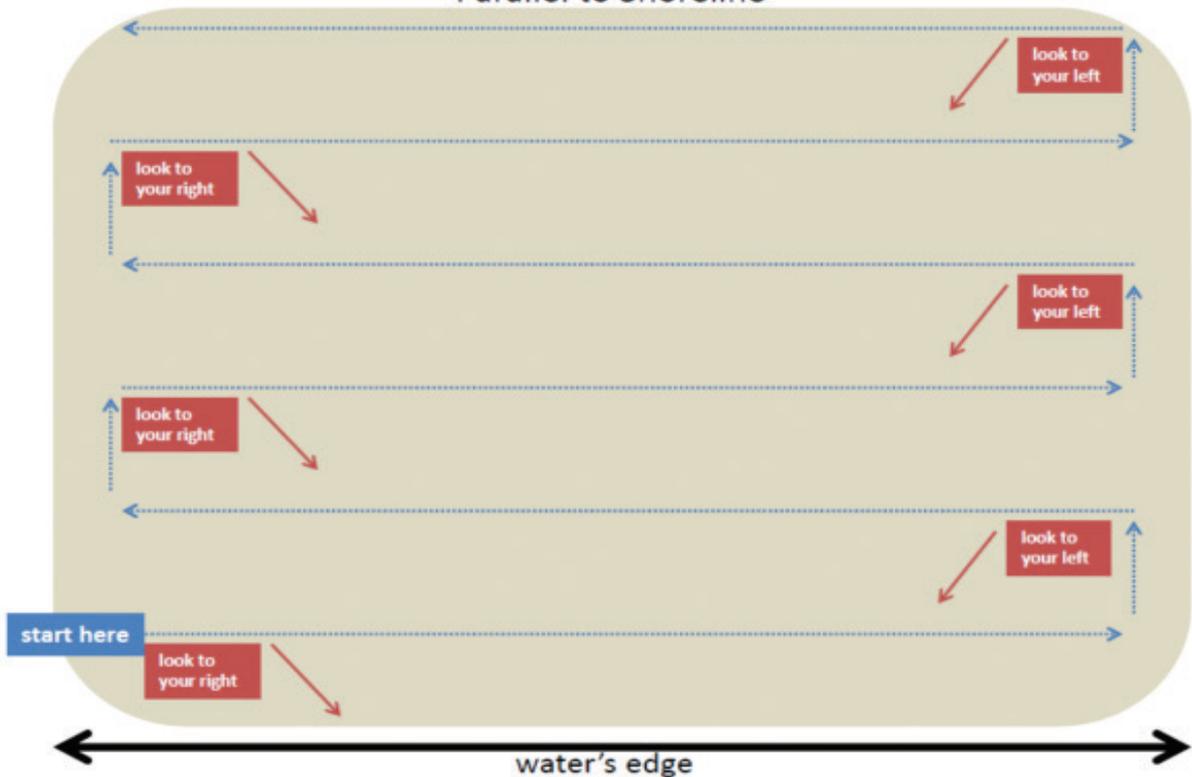
Appendix 5: Walking patterns for conducting beach surveys

Source: NOAA (Opfer, Arthur and Lippiatt, 2012)

Walking Pattern #1: Perpendicular to Shoreline

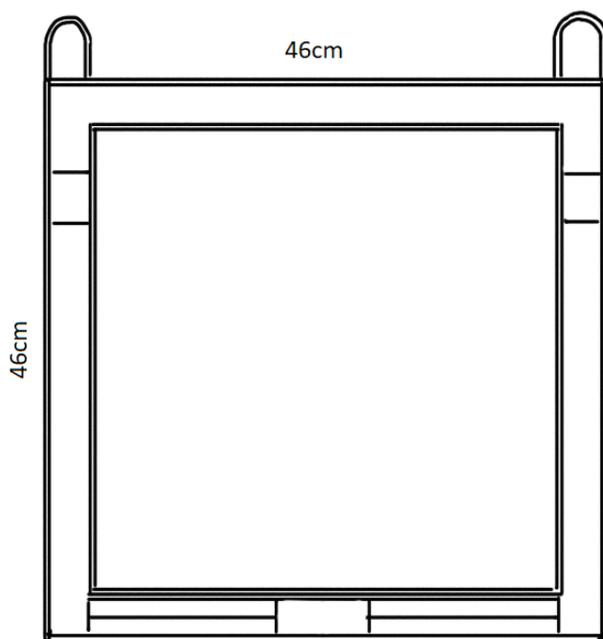
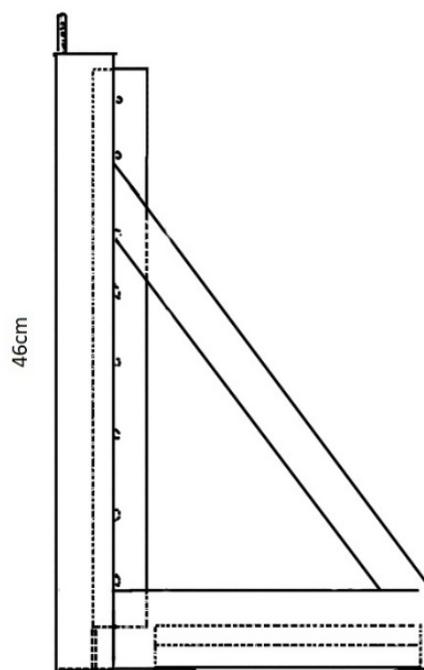
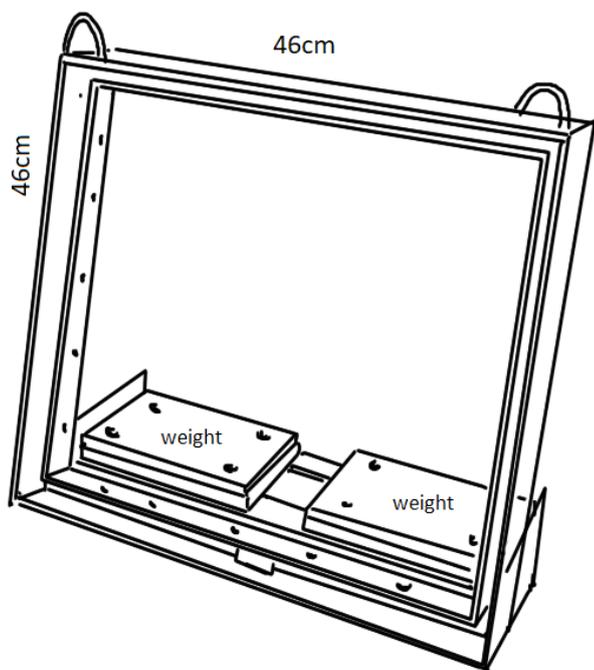


Walking Pattern #2: Parallel to Shoreline



Appendix 6: Designs for rectangular trawl construction

- 46cm x 46cm galvanised steel frame
- 2 x 5kg weights at bottom
- 2 x shackles or metal loops on one side (the top) for attachment to stabilising lines
- Ability to remove and reattach net



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