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Development of a Marine Debris Monitoring Decision Framework for APEC Economies

APEC Oceans and Fisheries Working Group

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ACRONYMS

African MLMM	Africa Marine Litter Monitoring Manual
Australia BYB	Bin Your Butt
Australia MDI	The Australian Marine Debris Initiative
British BCP	The Great British Beach Clean Programme
Chile LS	Chile Litter Scientists
China MDMP	China Marine Debris Monitoring Program
China NCCMP	China National Coastal Cleanup and Monitoring Project
COBSEA	Coordinating Body on the Seas of East Asia
CSIRO	The Commonwealth Scientific and Industrial Research Organization, Australia
EU MARLIN	EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project
EU MLW	Marine LitterWatch
EU MSFD TGML	MSFD Technical Group on Marine Litter in Europe
EU OSPAR MML	Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area
GPLBP	Global Plastic Leakage Baseline Project
HELCOM	The Baltic Marine Environment Protection Commission (Helsinki Commission)
ICC	International Coastal Cleanup
Indonesia MDMG	Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry
Indonesia SBDP	Indonesia Stranded Beach Debris Program
Israel CC	Israel Clean Coast
Japan DBDM	Japan Drifted Beach Debris Monitoring
Japan DLP	Disposable Lighter Project
Korea NBLMP	Korea National Beach Litter Monitoring Program
Korea RA	Korea Rapid Assessment
NOWPAP	Northwest Pacific Action Plan
NOAA MDMAP	Marine Debris Monitoring and Assessment Project, US
MDT	University of Georgia's (Marine) Debris Tracker App, US
MED DeFishGear	Marine Litter Assessment in the Adriatic & Ionian Seas
MSFD	Marine Strategy Framework Directive
New Zealand LI	New Zealand Litter Intelligence

UNEP/IOC GSMML	UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter
USA KAB CLPP	Cigarette Litter Prevention Program
USA NOAA CLPP	Cigarette Litter Pilot Project
USA Virginia BD	A Rising Concern: Reducing Balloon Debris through Social Marketing
Viet Nam MAPPL	Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline

EXECUTIVE SUMMARY

The problem of marine debris and microplastics has become an environmental issue garnering global attention and concern. In 2015, Sustainable Development Goals (SDG 14.1) set a goal to significantly reduce marine debris. At the 5th UN Environment Assembly in 2022, all Member States agreed to create a legally binding instrument on plastic pollution. In order to establish and implement goals in line with SDG 14.1, measurable quantitative indicators are needed. Therefore, monitoring the marine environment and marine wildlife has become an increasingly important subject of interest. A stronger response is needed in the APEC region than anywhere else to reduce the amount of plastic entering the sea and to reduce its harmful impacts. There is no common monitoring methodology at the APEC level, and there is a lack of harmonized effort due to the large gap in monitoring efforts between economies.

This document is the outcome of the project 'Development of a marine debris monitoring decision framework for APEC economies (OFWG 03 2020A)' that was implemented according to the APEC Marine Debris Roadmap. The purpose of the project is to help the APEC economies wanting to start a new monitoring program to identify and decide on a program closest to the objective they want to achieve, allowing them to leverage existing resources, and avoid duplication of effort or proliferation of unharmonized methods. Expected users of this document include economy officials, technical staff and practitioners, researchers, educators, environmental activists, and community group leaders. For the purposes of this project, only shoreline marine debris in roughly macro size (larger than 25 mm) is considered, but since some monitoring programs include smaller debris, this project also covers any visible debris as macro debris. At the end of Chapter 1, how to use the document is introduced.

In addition to shoreline monitoring programs implemented in large scale and understood as an activity requiring repetitive measurements, this project has included one-off studies and projects, including cleanup campaigns, if they were conducted repeatedly. A total of 31 monitoring programs or methodologies were collected and an inventory for the purpose of practicality is also included in Chapter 2 and Appendix 1. Assuming economy agencies and authorities are the ones overseeing the monitoring program, APEC economies wishing to start a new monitoring program may select one or more of the following five objectives: 1) Identifying baseline, state, or level of pollution; 2) identifying changes over time in the amount, composition, type, and source of debris; 3) conducting a spatial assessment of marine debris; 4) providing basic information to develop countermeasures; 5) Raising public awareness and building capacity.

To choose an optimal monitoring program that will help achieve the intended objectives, the users will select each of the following criteria while considering the available budget and resources: debris target (size and category); scale (spatial scale and site selection); data collection (training, interval, and measurement); management (quality management, database, and data analysis) in Chapter 3. The key questions presented under each criterion will assist to identify monitoring programs that are closest to the one the users hope to design.

Most monitoring programs categorize and record all kinds of marine debris, but there are a few programs that only monitor indicators or specific target items of interest that the users want to reduce. While most monitoring programs categorize by material, including plastics, some even categorize by use in order to get a better understanding of its source. To obtain data representing a spatial distribution of a economy, there must be an adequate number of survey sites and it is important to note that selecting only sandy beaches or gentle slopes may render biased results. If the users want to monitor on a domestic level, participation and partnerships of various groups are required, and surveys must be conducted using identical and consistent methodologies and training is essential. The most common monitoring interval is four times a year based on seasonal changes, but there are also monthly, bimonthly, and annual surveys. Surveys are mostly implemented from backshore to water edge along the fixed length (mostly 100 m) of shoreline and all debris is removed after the survey but in some cases only standing stocks are measured without cleanup. Generally, the number of debris per unit length is measured and sometimes even the weight, but there aren’t any monitoring programs only measuring the weight.

In order to obtain high-quality monitoring data, it is most common to provide a detailed manual and training for the surveyors to properly learn the method to collect accurate and consistent data. Errors should be minimized in all the processes of recording and submitting results. An excellent example of improving quality management in monitoring using an app is introduced in Chapter 3. Data is stored in the form of spreadsheet files or databases which are open to the public or closed. There is a very useful web database that includes more than 70 programs where users can customize one of the programs for their own purpose. The most basic data obtained through monitoring is the abundance of debris expressed as a number per length or area that meets the SDG 14.1 indicator proposed by UNEP (2021). Average abundance over time or space can be obtained by descriptive analysis. There are two examples to obtain a relatively detailed analysis result without a professional workforce. However, if the users need to evaluate the effectiveness of policy intervention, to find drivers affecting the abundance, or to obtain a predictive model, available workforces with considerable expertise are required.

The first draft document was significantly improved through reviews of the technical advisory committee and feedbacks of 27 representatives from 10 economies (Australia; Chile; China; Chinese Taipei; Indonesia; the Philippines; Korea; Peru; Thailand; and Viet Nam) and five technical advisors from Brazil, Chile, New Zealand, France, and USA in the virtual workshop held in June 22, 2022. Following the workshop, a consulting meeting was held to conduct a case study. Two case studies of Peru and Chile based on the objectives which the member state wants to achieve and suited to its needs are included in Chapter 4. Recommendations from the authors are included in Chapter 5 by a summary table and an example of the simplified decision framework.

1 INTRODUCTION

1.1 Background and Purpose

The problem of marine debris and microplastics has become one of the triple planetary crisis which include climate change, loss of biodiversity and ecosystem integrity, and pollution and waste[1]. The Asia-Pacific Economic Cooperation (APEC) economies have rapidly grown in recent decades, in many cases at the expense of environmental health including marine environments, and marine debris pollution has emerged as one of the most urgent issues to address in the region. Recent studies report that land-based plastic waste leaks into the ocean and aggravates the pollution in the Asian region (Jambeck et al., 2015; Lebreton et al., 2017; Meijer et al., 2019). In the sea, the use of fishing resources is active and a lot of plastic fishing gears are abandoned, lost, or discarded, and finally arrive at the North Pacific ocean (Lebreton et al., 2022; Lebreton et al., 2018). Marine debris causes serious threats to wildlife by entanglement and ingestion (Boerger et al., 2010; Hong et al., 2013; Nelms et al., 2016; Thiel et al., 2018) and to the marine economy (McIlgorm et al., 2022), including fisheries and aquaculture (Richardson et al., 2019), navigation safety (Hong et al., 2017), marine tourism (Jang et al., 2014), and food safety (Barboza et al., 2018; Lee et al., 2021) in the Asia Pacific region.

Understanding the current status of marine debris pollution through a monitoring program is the first step to address the problem in the globe. Monitoring marine debris can be carried out on seawater surface, on the seafloor, on shore, and on living organisms (GESAMP, 2019). There are multiple reasons for solely selecting shorelines for marine debris monitoring as the scope of this project. Shorelines are often considered first due to the accessibility or proximity to land-based sources. Large amounts of marine debris accumulate along shorelines playing a role of sink or trap (GESAMP, 2019; Turner et al., 2021). Shoreline monitoring can indicate both debris deposited locally from inland sources or on site, as well as debris from offshore sources (Brennan et al., 2018; Olivelli et al., 2020). It is more cost-effective than conducting monitoring in other compartments, such as water columns, seafloor, or the biota. Lastly, there are numerous programs that engage volunteers in monitoring shoreline debris and thereby provide the opportunity for the general public to fully engage in the efforts to find the root causes and solutions for marine debris.

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[1] https://www.unep.org/resources/resolutions-treaties-and-decisions/UN-Environment-Assembly-4

Over the last decades, there have been large investments in shoreline monitoring efforts to better understand marine debris pollution levels (Burgess et al., 2021; Lipiatt et al., 2013; OSPAR Commission, 2007; Ribic et al., 2010; Sheavly, 2007). However, the heterogeneity of the sources, distribution, and the fate of marine plastic debris were often identified as common challenges that complicated the designing of a uniform marine debris monitoring program (Ryan et al., 2009). To achieve specific goals and objectives, most monitoring programs have particular methods regarding: site selection, use of transects and quadrats within a selected site, interval, debris size, classification categories (material type, usage, and/or origin), sampling at the sediment surface or surface and buried debris, measuring standing stock or accumulation rate, measurement units (number, mass, volume per length or per area), and surveyors (citizens, trained citizens, paid staff, or experts). Such variations create difficulties in collating and comparing results across monitoring programs (Browne et al., 2015; Serra-Gonçalves et al., 2019; Uhrin et al., 2022)

In addition, ambiguities on designating the responsible entity for data collection and accumulation, requisite information on metadata, data quality control processes (pictorial manuals, surveyor training workshop, or cross-checking data records), technical processes for data analysis, utilization of data results and best practices to develop mitigation policies (on domestic, local, and community levels), and financial requirements for long-term monitoring often hinder the implementation of new monitoring programs.

There have been studies on harmonizing or standardizing methodologies of monitoring programs that could be applied to wider geographic regions. The UNEP/IOC Guidelines (Cheshire et al., 2009) were the first to attempt such efforts followed by an updated guideline by GESAMP (2019) that includes microplastic surveys. More recently there has been effort to harmonize monitoring methodologies and their results in COBSEA (COBSEA and CSIRO, 2022). Despite these commendable efforts, there are many challenges yet to be resolved when considering inconsistent data collection, lack of harmonization, and rapid expansion of monitoring efforts.

Comprehensively understanding the pollution levels in different APEC economies with varying conditions pose many difficulties and it is often unclear which of the many monitoring programs are most suitable to specific monitoring needs. Finding a suitable monitoring methodology or program requires a balancing act of weighing the benefits and challenges which is a major undertaking. Even when a monitoring methodology or program is ultimately selected or designed, various stages of implementation demand resources, processes, and requisite capacity to ensure that data collection is attainable and useful. While APEC economies may find or tailor existing monitoring methodologies or programs as they see fit, many will benefit from detailed guidance that will help realize the tradeoffs of different approaches and the efforts needed to attain short and long-term goals.

In 2019, APEC Senior Officials agreed to an APEC Roadmap on Marine Debris that emphasized the importance of enhancing the efforts on understanding the impacts and costs of marine debris and to develop countermeasures on mitigating its impacts on sustainable economic growth in the Asia-Pacific region.

This project has developed a decision framework to help APEC economies navigate the potentially daunting process in deciding a monitoring methodology or program best suited for the needs and goals of prospective users and operators alike. Improved capabilities to better understand the prevalence of marine debris will enable APEC economies to combat marine debris more effectively, increase mitigation efforts while recognizing unique circumstances, and share best practices.

This project includes the following: 1) a review of all available shoreline marine debris monitoring methodologies and programs, comparing them according to monitoring objectives, survey intervals, categorization of debris, measurement units, and more; 2) an assessment of monitoring programs and methodologies through a practical lens, particularly when applying them *in situ* in regions lacking technical and financial resources; 3) an establishment of a marine debris monitoring decision framework that will aid practitioners or stakeholders when creating or operating their own monitoring programs; and 4) guidelines, recommendations, and advice on shoreline monitoring of marine debris.

1.2 How to use this document

This document presents all existing shoreline marine debris monitoring programs or methodologies as of the end of 2021. Additional cases are also included that can be used as monitoring programs. Details of each are given in the Appendix. Chapter 2 presents the method to develop the decision framework of marine debris monitoring.

Important elements and decision criteria were listed in Chapter 3 where definitions and detailed descriptions of each criterion are provided with key questions that may arise under each criterion in the form of a decision framework or tree. Users can plan their monitoring programs by selecting their preferences using the decision framework or tree.

Chapter 4 shows two case studies of APEC member economies resulted from consulting meetings following the virtual workshop for the feedback on the draft decision framework. In Chapter 5, recommendations that should be considered first for each element and criterion are summarized in the form of table and decision-making framework. The inventory of the attached excel form contains all program information. It will be useful to use the function in Excel sheet to select any cell of criteria, ‘Data’, ‘Filter’, and select the column header arrow to approach the closest case to what users need.

2 METHOD

2.1 Scope

Marine debris (or litter) is defined as ‘any persistent, manufactured or processed solid material, discarded in the marine and coastal environment’ (UNEP, 2005). Marine debris refers not only plastics but also metal, paper, processed wood, glass, fabric, and others, regardless of size. Marine plastic debris means only plastic material. Macro debris indicates debris larger than 25 mm in diameter and meso debris refers to debris from 5 to 25 mm. Debris smaller than 5 mm are rarely called micro debris and are usually called microplastics because in the case of such a small-sized marine debris, plastics are the main concern, so most studies only target plastic materials.

This project only focused on monitoring efforts for beaches and shoreline environments and excluded monitoring programs related to other environmental compartments (e.g., seafloor, sea surface). Monitoring programs that focused on the impacts of marine litter on ecosystems, marine life, economy, and environmental safety, have been excluded. Most of the monitoring programs used in this project are those that are still being used actively, but a few completed monitoring programs are also included, as they are deemed to be useful and can be applicable for a particular purpose.

According to GESAMP (2019), ‘monitoring can be strictly defined as the repeated measurement of a characteristic of the environment, or of a process, in order to detect a trend in space or time’. Extensive marine debris monitoring efforts have been undertaken in various marine environments. They differ in purpose, method, scope, and interval, rendering disparate results. This project basically focuses on examining monitoring programs that are repeatedly conducted locally, domestically, regionally, and globally if possible.

A total of 39 cases[2] were derived from research papers, reports, and websites found during online searches using search terms such as marine debris, litter, plastic, monitoring, shore, beach, coast, and guideline in Google Scholar. Shoreline debris monitoring programs were inventoried based on the following process (Figure 1). First, keeping in mind that monitoring

[2] In this document, ‘program’ refers to the combined components one must undertake for a monitoring survey and ‘methodology’ refers to a monitoring guideline or procedure, and ‘method’ for individual options for criteria in implementing surveys. Programs or methodologies are integrated and referred to as 'cases'.

is an act of repeatedly examining and measuring the changes in marine debris (GESAMP, 2019), this document includes all monitoring programs that fall under this definition (15 programs or methodologies). One-off studies or surveys for a particular research purpose, cleaning-oriented programs, and mobile app usage programs were also included if they were a good reference for developing monitoring programs (16 cases). All monitoring programs listed in GESAMP (2019), Smail et al. (2020), and Serra-Gonçalves et al. (2019) are included in the cases. NOWPAP (2007) and HELCOM (2018) are not included in the list because those are a guideline by compiling information on shoreline marine debris monitoring in the Northwest Pacific and the Baltic Sea regions. NOWPAP (2007) proposed shoreline monitoring methodology for marine debris, however, it did not either provide the method in detail or datasheet for recording, and that recommended use ICC data sheet. HELCOM introduced monitoring methods briefly in their guidelines (2018) and in the BLASTIC report it suggested two common beach litter monitoring methods, OSPAR and Marlin, as commonly used in the Baltic region. two reports, however, do not provide detailed monitoring methods that should be applied in the field survey. Then 31 cases were selected in total, and their basic information and detail are listed in Appendix 1.

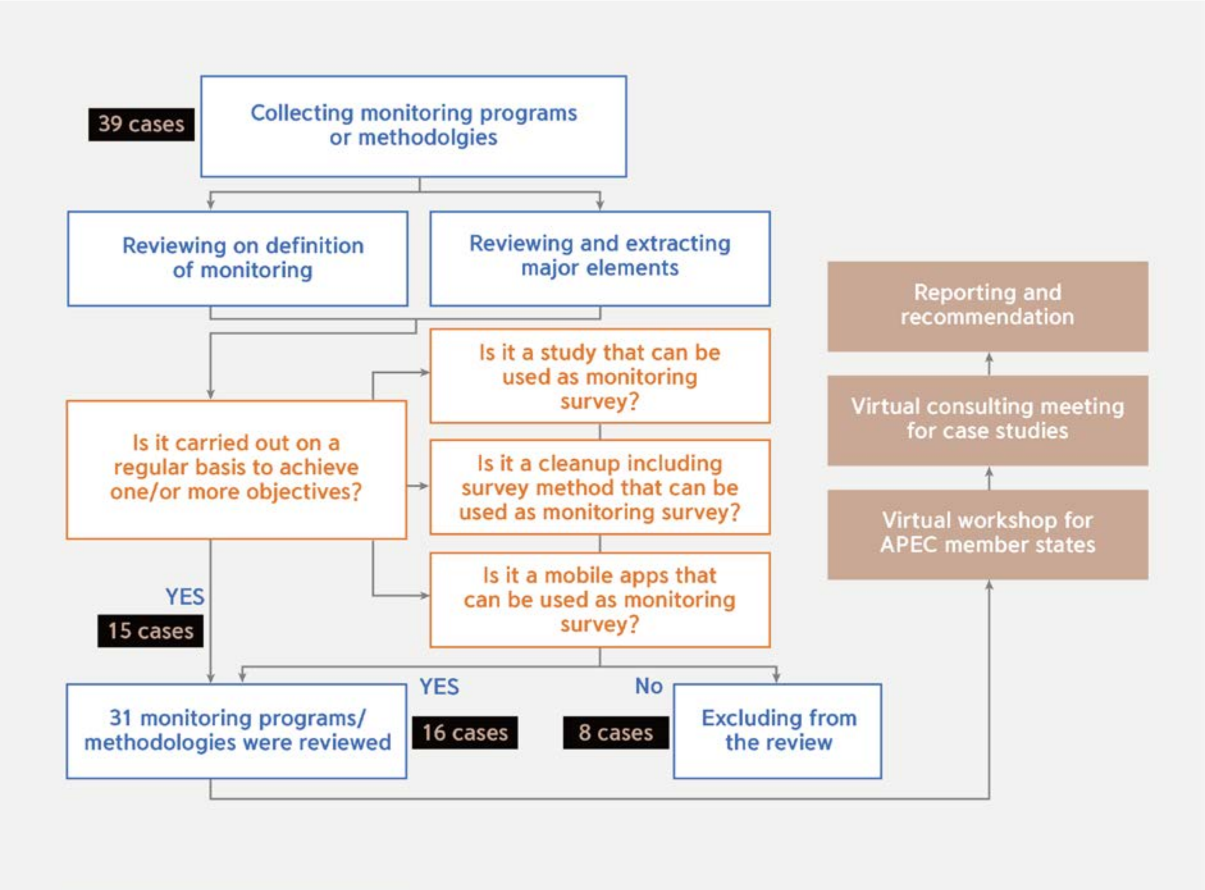


Figure 1. The process to extract monitoring programs or methodologies, to select the cases for review, and to conduct case studies based on draft decision framework.

2.2 Reviewed programs

We reviewed a total of 31 cases, and they can be divided into four types (Table 1). The programs that repeatedly measure changes in the amount, composition, or type of marine debris according to the original monitoring definition were classified as R (Regular monitoring), and a total of 15 cases fall into this category. Six programs were repeatedly implemented for a certain period of time to identify spatial and temporal changes but were completed, they were classified as S (Study). S (Studies) were implemented from seven months to five years and survey intervals were diverse from twice a month to six months. Among them, Israel Clean Coast (Israel CC) lasted just seven months as a monitoring research program. In this program they surveyed marine debris on Israel's Mediterranean coast twice a month and developed a clean-coast index in which the coast would be classified into five levels by dirtiness. It can be a tool for evaluating the actual coast cleanliness and measuring success of educational campaigns to reduce marine debris (Alkalay et al., 2007) and much subsequent research has used the index (Al Nahian et al., 2022; Asensio-Montesinos et al., 2021; Bouzekry et al., 2022; Santodomingo et al., 2021; Sibaja-Cordero and Gómez-Ramírez, 2022; Vlachogianni et al., 2018). On the other hand, Korea Rapid Assessment (Korean RA) surveyed standing stock of the debris using a visual scoring indicator quarterly for two years (Lee et al., 2019). The former has the advantage of being able to evaluate the pollution level of the coast at the same time as monitoring, and the effect of education and outreach programs can be evaluated, and the latter has the advantage of being able to determine the standing stock of the debris. For these reasons we included two programs in the cases. The Global Plastic Leakage Baseline Project (GPLBP) was also included in this category because it evaluated marine debris around the world once or more times without collection and these data can serve as a baseline for the region.

Most cases investigate all items along the shoreline, but there are also cases where monitoring can be more narrowly focused and simplified, and where effort can be saved by examining only specific items. Four of the cases fall into this category, which are A Rising Concern: Reducing Balloon Debris through Social Marketing (USA Virginia BL) (S), Disposable Lighter Project (Japan DLP) (S), Cigarette Litter Pilot Project (USA NOAA CLPP) (C), Bin Your Butt (Australia BYB) (C), and Cigarette Litter Prevention Program (USA KAB CLPP) (C). Among them, USA Virginia BL surveys balloons, Japan DLP surveyed lighters, and USA NOAA CLPP, Australia BYB, and USA KAB CLPP targets cigarette butts. The programs of which the goal is to clean up the coast and raise awareness, and in a specific area where activities were conducted as monitoring were classified as C, and four programs belong to this category. International Coastal Cleanup (ICC) investigates all visible items in as unified way more than 30 years. However, it has not been controlling survey site, participants, data quality, thus it cannot be classified into Regular monitoring (R) or Study (S). It has contributed to cleaning coastal debris and raising awareness in more than 100 countries. In this regard, we classified it into the category (C) (Table 1).

In recent years, marine debris surveys using apps have attracted more attention and are mostly used in citizen science. They are classified as “A” standing for “App-based survey”. Three of them can be used globally (Clean Swell, Litterati, University of Georgia’s (Marine) Debris Tracker App (MDT) and the other three are used regionally (Marine LitterWatch (EU MLW), New Zealand Litter Intelligence (New Zealand LI), The Australian Marine Debris Initiative (Australia MDI)). These projects were included because they can be modified and applied as monitoring programs if the survey length and width are measured. They have advantages for serving monitoring objectives to raise awareness and build capacity to combat marine debris because they are generally easy to use and disseminate to the public.

Table 1. Typology and characteristics of the 31 in this document (R: Regular monitoring; S: Study; C: Clean-up and awareness-oriented survey; A: Mobile application-based survey).

Classifi-cation	Program	Abbreviations	Project/ Method
R	UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter	UNEP/IOC GSMML	Method
R	MSFD Guidance on Monitoring of Marine Litter in European Seas	EU MSFD TGML	Method
R	EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project	EU MARLIN	Project
R	Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area	EU OSPAR MML	Project
R	Marine Debris Monitoring and Assessment Project	NOAA MDMAP	Project
R	China Marine Debris Monitoring Program	China MDMP	Project
R	China National Coastal Cleanup and Monitoring Project	China NCCMP	Project
R	Indonesia Stranded Beach Debris Program	Indonesia SBDP	Project
R	Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry	Indonesia MDMG	Project
R	Japan Drifted Beach Debris Monitoring	Japan DBDM	Project
R	Korea National Beach Litter Monitoring Program	Korea NBLMP	Project
R	Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline	Viet Nam MAPPL	Project
R	The Great British Beach Clean Programme	British BCP	Project
R	African marine litter monitoring manual	African MLMM	Method (manual)
R	Chile Litter Scientists	Chile LS	Project
S	Marine Litter Assessment in the Adriatic & Ionian Seas	MED DeFishGear	Project
S	Korea Rapid Assessment	Korea RA	Project
S	Israel Clean Coast	Israel CC	Project
S	Balloon litter on Virginia's remote beach	USA Virginia BL	Project
S	Disposable Lighter Project	Japan DLP	Project
S	Global Plastic Leakage Baseline Project	GPLBP	Project
C	Cigarette Litter Pilot Project	USA NOAA CLPP	Project
C	Bin Your Butt	Australia BYB	Project
C	Cigarette Litter Prevention Program	USA KAB CLPP	Project
C	International Coastal Cleanup	ICC	Project
A	Clean Swell	Clean Swell	Project
A	Litterati	Litterati	Project
A	University of Georgia's Marine Debris Tracker App	MDT	Project

A	Marine LitterWatch	EU MLW	Project
A	New Zealand Litter Intelligence	New Zealand LI	Project
A	The Australian Marine Debris Initiative	Australia MDI	Project

These 31 cases were selected as of the end of 2021, so there may be more cases that have started or have been reported recently. There are also many more research cases that can be applied as monitoring programs (e.g., targeting specific bottles having information of the brand, manufacturer, or economy of manufacture (Ryan et al. al., 2019); analysis of single use plastics or fishing gear after completing investigation of all the items (Simeonova and Chuturkova, 2020; Vlachogianni et al., 2020). If the surveys are to be performed repeatedly, they can serve monitoring goals to identify levels and sources and to evaluate spatio-temporal trends. The survey results before and after policy establishment and implementation can be used as performance indicators to the success of the policy.

Many countries around the world conduct nation-wide shoreline debris monitoring programs, e.g., China, Indonesia, Japan, Korea, USA, etc. As far as we know, 9 of 20 economies in APEC region have 14 monitoring programs in total. One program was completed, and the others are still ongoing (Table 2).

Table 2. Nine APEC economies (n = 14) have engaged in the shoreline marine debris monitoring program

Economies	Entities	Status	Year started	Acronyms
Australia	Governmental Institute	In progress	2017	GPLBP
	NGO	In progress	2004	Australia MDI
Chile	University	In progress	2008	Chile LS
China	Government	In progress	2007	China MDMP
	NGO	In progress	2014	China NCCMP
Indonesia	Government	Complete	2017	Indonesia MDMG
	Research Institute	Complete	2018	Indonesia SBDP
Japan	Government	In progress	2015	Japan DBDM
Korea	Government	In progress	2008	Korea NBLMP
	Government	Complete	2016	Korea RA
New Zealand	NGO	In progress	2018	New Zealand LI
USA	Government	In progress	2010	NOAA MDMAP

	NGO	In progress	1986/2014	ICC/Clean Swell
Viet Nam	NGO	In progress	2016	Viet Nam MAPPL

2.3 Introduction to new technologies

We added monitoring studies using new technology (Table 3). Recently, environmental monitoring using the latest technologies such as drones and unmanned aerial vehicles is increasing and data from these technologies can be used effectively to understand pollution levels of marine debris in broad, isolated or protected marine environments and provide baseline data. They can serve to estimate spatial and temporal trends of marine debris if the surveys with them are to be implemented repeatedly. The technologies have advantages to operate autonomously, provide high resolution images, and become affordable tools along with machine learning techniques for automated detection of litter items on drone images (Andriolo et al., 2022). Furthermore, the object-based approach allows measuring the size of debris items and computing the total area covered by marine debris on the beach (Andriolo et al., 2022; Takaya et al., 2022). They will enable low-cost long-term beach litter monitoring allowing monitoring wide range in a standard way (Takaya et al., 2022). Escobar-Sanchez et al. (2021) suggest that drone monitoring could be an option in the future for heavily polluted beaches by a lot of debris over 50 cm in size.

Table 3. Programs and studies using new technology to be helpful for monitoring design

Method	Characteristics	Reference
Unmanned Aerial Vehicle	Low cost, high resolution, and capacity of covering large area	Fallati et al. (2019)
	Low cost, time saving and capacity of covering large area	Martin et al. (2018)
	Unmanned aerial vehicle (UAV) surveys and image processing based on deep learning	Kako et al. (2020)
Webcam image	Detecting plastic debris using webcam images	Kataoka et al. (2012)
Balloon	Low altitude remote sensing method using a balloon with a digital camera	Kako et al. (2012)
Drone	Low cost, time saving and capacity of covering large area	Martin (2018)
	Generating density maps for the beached debris, assisting in the identification of the debris in the Marine Protected Areas	Deidun et al. (2018)
	Image analysis from drone should be tested to explore this tool for fast-screening of non-accessible sites, fragile ecosystems, floating debris or heavily polluted beaches.	Escobar-Sánchez et al. (2021)
	Drone images were used to identify beached litter and evaluate the effectiveness of the cleanup activities by comparing images taken before and after cleanup in Seto Island in Japan.	Takada et al. (2022)
	The little drone project employs new technology like unmanned aerial vehicles to perform monitoring in beaches belonging to the Spanish national program	https://litterdrone.aebam.org/index.php/proyecto/?lang=en
Drone and polarimetric imaging (PI) cameras	NOAA's National Centers for Coastal Ocean Science (NCCOS), NOAA's MDP, and Oregon State University (OSU) partnered to investigate three emerging technologies with the potential to utilize them for shoreline marine debris assessments.	https://uxsrto.research.noaa.gov/News/Articles/ArtMID/6699/ArticleID/979/Marine-Debris-Detection-with-UAS-Machine-Learning-and-Polarimetric-Imaging

3. KEY QUESTIONS AND DECISION FRAMEWORK

A marine debris monitoring program should be designed using a logical and adaptive framework (GESAMP, 2019). It tends to be driven by goals and objectives and is hierarchical. After setting monitoring goals/objectives, it is important to identify what is needed to achieve them. The process can be guided by key questions relevant to main elements of the monitoring program. We extracted 5 major elements and 11 decision criteria from reviewed monitoring programs (Table 4). We added description to each criterion for users to understand the characteristics and execution of monitoring. It must be noted that such classifications of these monitoring programs may require updates to reflect the current practices and information, because programs and monitoring methods do change over time.

Cost is one of the most important criteria to consider when designing a monitoring program. The costs associated with marine debris monitoring will vary according to the objectives. The objectives may need to be adjusted by finding cost-effective alternatives that will still provide adequate monitoring methodologies. Normally, shoreline marine debris monitoring costs much less than those done underwater or on seafloors (GESAMP, 2019). Sufficient sampling over time to detect debris load trends on long and complex coastlines is more costly than capturing the ranking of item types across small target areas. However, it is missing from the criteria due to a lack of information on cost.

Table 4. Element of monitoring, decision criteria and their description in this document

Elements of Monitoring	Decision Criteria	Decision Criteria Description
Goals / Objectives	**Objective**	Thirty-one programs were regrouped according to 5 objectives. 1) Identifying baseline, state, or level of pollution 2) Identifying changes over time in the amount, composition, type and source 3) Conducting a spatial assessment of marine debris 4) Providing basic information to developing countermeasures 5) Raising public awareness and building capacity
Debris Target	**Size**	· Size of target debris are classified into mega (> 50 cm), macro (25 mm ~ 50 cm), meso (5 ~ 25 mm), and micro (< 5 mm). Most marine debris monitoring programs target macro debris. Users of this document will be primarily interested in macro debris. Therefore, smaller or larger debris than macro debris are dealt with briefly.
	Category	· All debris items along the shoreline are usually classified into material categories (e.g., plastics, processed wood, glass, fabric, metal, paper, etc.) or occasionally into usage categories (e.g., fishing gears, packaging, personal hygiene, etc.). · Specific items are selected as indicators (e.g., cigarette butts, balloons, disposable lighters).

Scale	Spatial Scale	· Spatial scale of monitoring will be on domestic, regional, local levels.
	Site Selection	· Sites should be selected to secure representative data within a given scale. · Survey sites can be spatially distributed or selected by stratified random sampling. On-demand site selection (arbitrary site selection by surveyors) also commonly used, but limit uses of the data. · Number and environmental conditions (e.g., length of the beach, substratum type, slope, etc.) should be considered.
Data Collection	Training	· The training method for the surveyors should be decided according to the difficulty of the survey method.
	Interval	· Intervals between surveys could be annual, seasonal, (bi) monthly, daily or occasional.
	Measurement	· Number, weight, or volume of debris over length or area of shoreline are measured and number per length is the most common expression of abundance. · In most monitoring programs, marine debris in the survey area is collected, measured and then removed, but in some cases, it is left untouched and only the numbers are counted or pictures are taken. · In some cases, marine debris in an entire section of the beach is surveyed or transects or quadrats are set up to measure the amount of debris.
Management	Quality Management	· Quality management consists of activities to improve the accuracy of the on-site survey (including training, joint survey, etc.) and measures to increase the reliability of the collected data (data verification).
	Database	· Databases (DB) are used for restoring and maintaining the monitoring results. Creating customized DBs requires a significant amount of money. · Recently, a number of web-based databases for marine debris surveys have been created, some of which require the approval of an administrator before registering the data, while others are open and publicly available. · Publicly available databases allow for broader reuse of the data.
	Data Analysis	· Descriptive statistics such as the amount and proportion of marine debris by region and time can be obtained through the analysis of monitoring results. · Simple descriptive statistics can be obtained using a web-based DB, but the evaluation of temporal trends and the analysis of the drivers that influence the generation of marine debris requires considerable expert effort.

Figure 2 denotes the procedural steps to take when planning a monitoring program. By following the steps of each criterion in order, one will be able to find a shoreline debris monitoring program that meets the desired goals and conditions. For example, it is crucial to first determine the goals and objectives of a monitoring program and to anticipate questions and issues that could be addressed through monitoring. The next step is deciding on a geographic scope or scale of the monitoring program and the target debris. Once these criteria are determined, the choice for a monitoring method most suitable for one's monitoring program will become more evident. Users may realize that achieving the initial goal may be difficult due to a lack of resources or limited circumstances. In such cases, goals and objectives must be adjusted. Furthermore, since each criterion composing the monitoring program is interdependent, criterion adjustments and repeated revisions of the monitoring method may be necessary. The overall cost of the monitoring program must be considered so that it can be carried out until the goals and objectives are met. If the cost of the monitoring program becomes a serious impediment to the overall success of the program, it may be necessary to readjust the methods and the goal to ensure that the monitoring program can be appropriately funded. In the following sections, each criterion is explained with a decision framework or tree and examples. The criteria in the decision trees are sometimes not mutually exclusive, and does not include all of the example programs. Still, they represent the combination of options you have chosen for each criterion and are a good starting point for designing more specific monitoring programs.

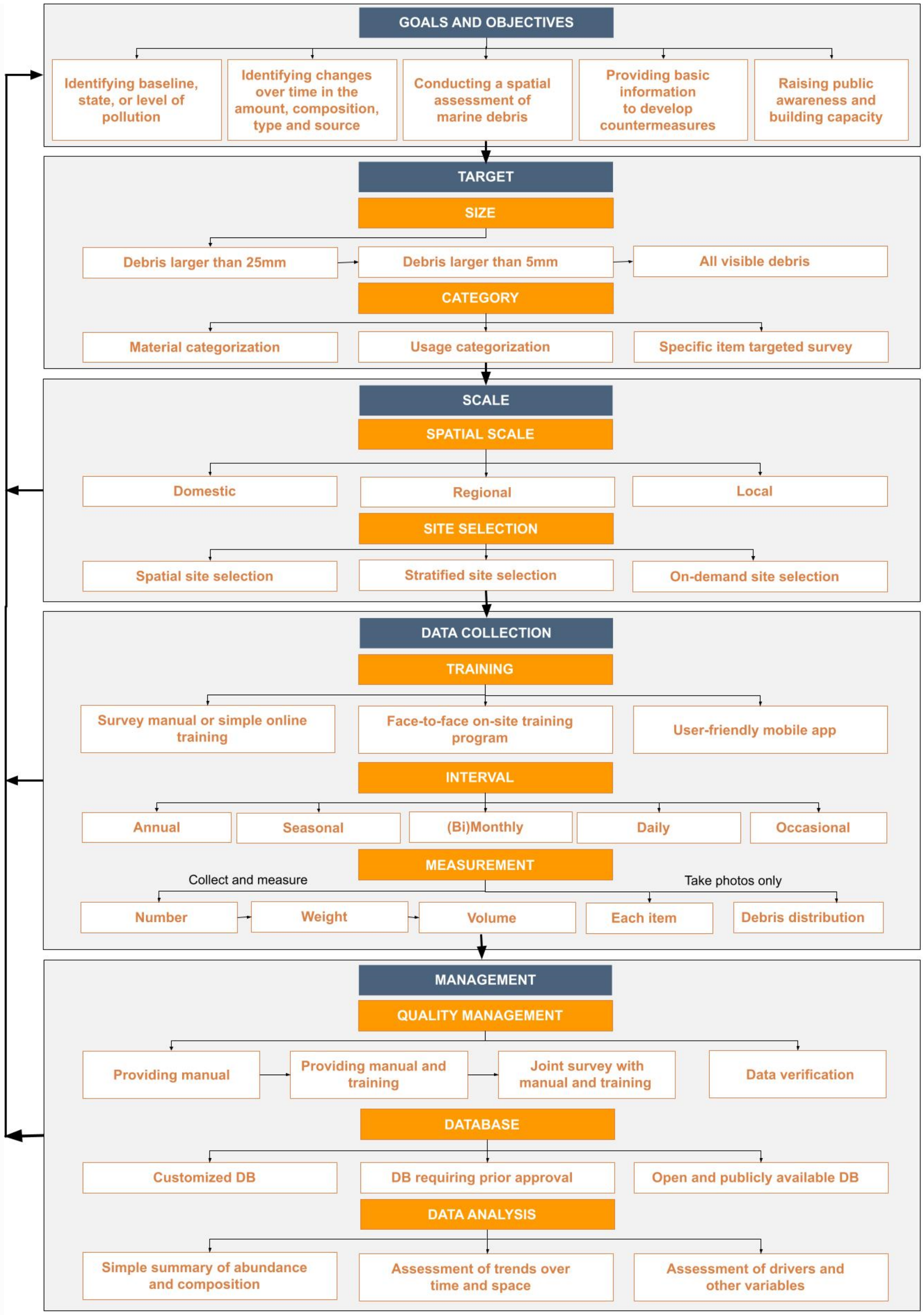


Figure 2. Decision flowchart for developing a shoreline marine debris monitoring program. The order of criteria can be changed according to the users' intention.

3.1 Goals and Objectives

Before deciding on a monitoring methodology, it is crucial to first determine the goals and objectives of a monitoring program and to develop questions that could be addressed through monitoring (GESAMP, 2019). Generally, goals are the desired result a monitoring program wishes to achieve and objectives are specific actions and measurable steps to achieve the goal. Sometimes it was presented in accordance with the definition of goal and objective, but there were also cases where goal, aim, and objective were used with similar meanings.

In this document, the 31 programs were synthesized and reclassified into five objective categories and added in a separate column of Table A5 in Appendix 1: 1) identifying baseline status, or pollution levels of shoreline debris; 2) identifying changes over time in the amount, composition, type, and source of debris; 3) conducting a spatial assessment of marine debris (particularly to compare between regions and countries); 4) providing basic information to develop countermeasures; and 5) raising public awareness and build capacity. When designing monitoring, objectives can be a single or a combination of a couple of objectives described above (Figure 3). By selecting one or more of these objectives, a monitoring methodology will be structured so that the monitoring results can contribute to achieving the objectives.

For the first objective, the pollution level can be assessed with an initial survey when the monitoring program begins. The initial survey result will provide baseline data and pollution levels of marine debris at the designated monitoring site(s). For all monitoring, it is recommended to estimate the flux of the debris into and out of the shore according to time by repeating the survey at regular intervals after removing the debris at the first survey (Barnardo and Ribbink, 2020; GESAMP, 2019). Through the subsequent monitoring, temporal and spatial changes will be assessed by comparing the results of the surveys with that of the initial survey.

Therefore, achieving the first objective is fundamental to the rest of the objectives which are to identify changes over time in the amount, composition, type, and source of debris (Objective 2) and conduct a spatial assessment of marine debris (particularly to compare between regions and countries) (Objective 3). Most of the monitoring programs which are classified R (Regular monitoring, Table 1) can achieve the first, second and third objectives at the same time. This is because they conduct the survey on a regular basis and classify the debris by material or material and usage so that we can elucidate the sources, composition, and the spatio-temporal trends. Specifically, Objectives 1, 2 and 3 are related to the analysis of the monitoring result. For example, the average abundance of all sites in a monitoring program will help us to identify the pollution level in the encompassing monitoring region area. Determining differences between sampling time and space with detailed analysis of the monitoring data will inform variations of each monitoring component by time and space. Finally, the result can serve to achieve Objectives 4 and 5. In fact, all objectives should be addressed in different ways when classifying and discussing monitoring methodology, yet they are complementary to each other and achieved in a unified way in real practices of many monitoring programs. The results from the regular monitoring can provide various information for policy makers to develop countermeasures against shoreline debris (Objective 4) and for education or outreach program makers to design awareness campaigns and education programs (Objective 5).

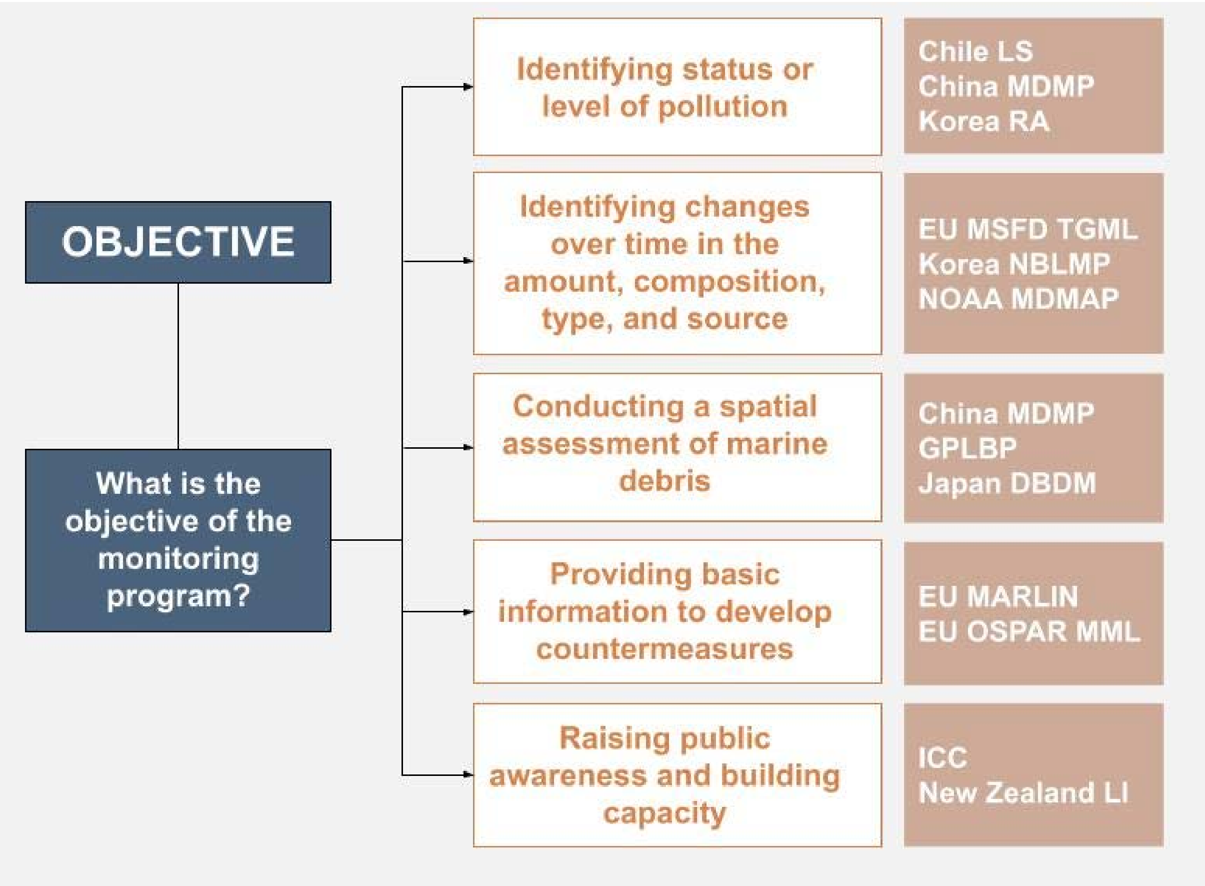


Figure 3. Decision framework on objectives and selected examples. Note that these monitoring objectives and programs are not mutually exclusive. Table A5 in Appendix 1 presents the objectives of individual examples.

The monitoring programs or studies such as MED DeFishGear and Israel CC from category S were conducted as regular monitoring with a fixed period. Although they were completed, they can serve as regular monitoring and contribute to the Objectives 1 to 5 if carried out on a regular basis in the future. USA Virginia BL and Japan DLP monitored specific items such as balloons and lighters, providing the pollution levels and the spatial and/or temporal trends to develop reduction strategies and awareness campaigns. These programs of the targeted item can be more effective and practical and serve the five objectives described above if the policy makers combat these debris. It is possible to identify the pollution levels of the particular item or overall debris with monitoring programs grouped C (Cleanup) and A (App-based survey) if these are to be carried out regularly on a broad scale and more efforts are invested to control the data collection. They will serve for the monitoring Objectives 1 to 5 in an individual way.

3.2. Debris Target

3.2.1 Size

[Key question] What size range of debris are you interested in?

Debris sizes are one of the most important elements when monitoring marine debris. Initially deciding on a target size will ease the following steps. Setting a target size will determine the difficulty of the monitoring effort required for conducting the surveys. Marine debris monitoring programs predominantly set target sizes to 25 mm or larger. It is recommended that governmental agencies or administrations that starts to monitor marine debris prioritize macro debris (GESAMP, 2019; Ryan et al., 2020; Uhrin et al., 2022). For macro debris sampling from shorelines, equipment, processing collected debris, and analyzing data are all available at a relatively low cost. Macro debris bears more information about the source than smaller-sized debris, making it easier to set policy goals from these data that can lead to mitigating the source (Figure 4).

When analyzing debris that is smaller than 25 mm, a considerable amount of time is required to separate target items from substrata (environmental matrices). This meticulous process can become more difficult, especially when the target size is 5 mm or smaller and will invariably require specialized equipment such as a microscope and an FTIR (Fourier transform infrared). With a heightened international interest in microplastics, the demand for monitoring microplastics has also increased.

Many programs reviewed in this project have targeted macro debris (e.g., EU MARLIN, Indonesia MDMG, Japan DBDM, Korea NBLMP, NOAA MDMAP, Viet Nam MAPPL) (Figure 4). The upper bound size of macro debris is not defined in most of the programs. In the case of EU MARLIN and OSPAR, mega debris (>50 cm) was separately surveyed in an extended section (1 km) outside the selected 100m area of the beach where macro debris was being surveyed. However, a 1000 m monitoring survey for larger debris is no longer obligatory from 2017 onward (OSPAR commission, 2017). GPLBP led by Australia's CSIRO records debris that is visible from standing human height where typically nurdles and smaller items are visible and identifiable. China MDMP and New Zealand LI record debris that are 5 mm or larger. African MLMM mainly targets macro debris (> 25 mm), but it also provides survey methods that can be applied when investigating smaller size groups (meso (5-25 mm) and micro (2-5 mm) debris). In any case, monitoring programs should be consistent in target size. The definition of debris size classes can be changed. However, it is not advisable to modify the range of the target size in the middle of the monitoring program because comparability of the data over time will be diminished.

The ICC, a cleanup campaign with a 35-year history, used to set 25 mm as its minimum target size for more than 25 years. This is often the size of bottle caps and cigarette butts. With recent growing interests in microplastics, starting several years back, Ocean Conservancy (OC) has asked ICC participants to record the number of small pieces of plastics in the Clean Swell app, a mobile application, which caused inconsistency. Recording small debris items for shoreline monitoring could provide interesting information but including microplastics effects the overall results, so it is better to group the data separately by size.

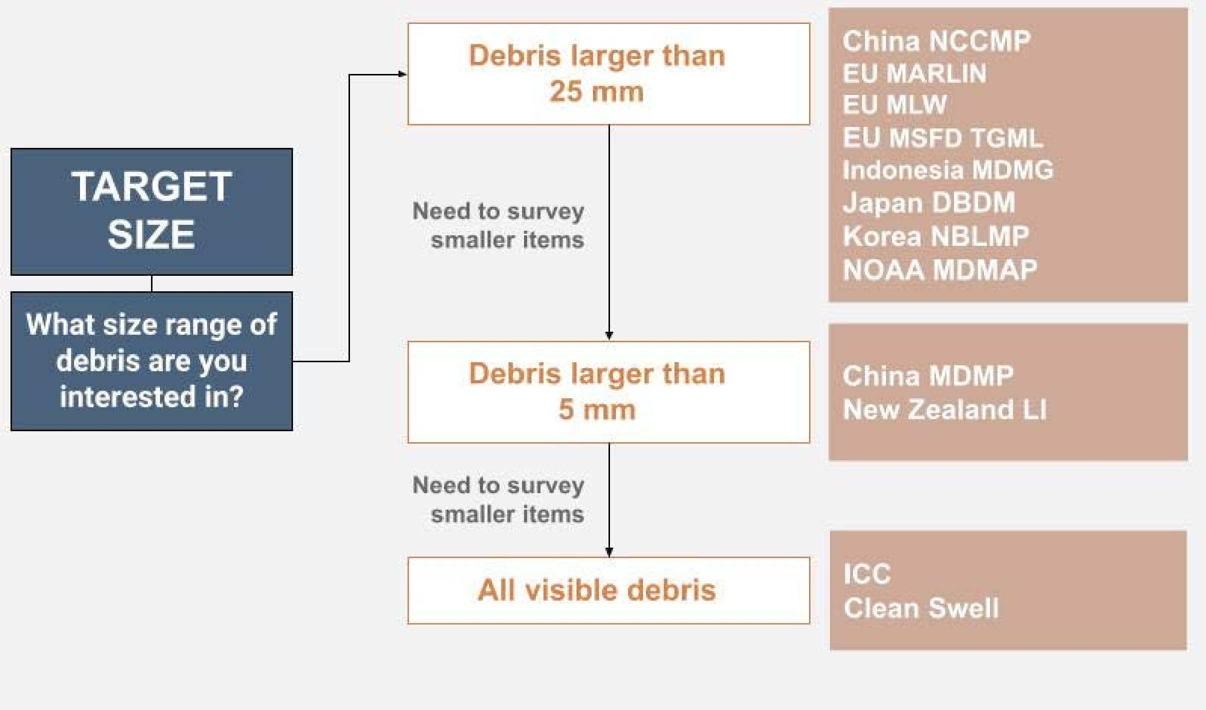


Figure 4. Decision framework on target sizes and example. Table A6 in Appendix 1 presents the target size of individual examples.

3.2.2 Category

[Key question] Do you plan on surveying all kinds of marine debris or a specific target item?

Most monitoring programs survey all kinds of macro debris found along shorelines and report the quantitative information in a hierarchical frame (an approach used in the GESAMP (2019) report) that describes the main categories (materials or usage) and subcategories (individual items under each main category) (Figure 5). Material categories in many programs consist of plastic, processed wood, glass, paper, rubber, fabric, and mixed material (UNEP/IOC GSMML, NOAA MDMAP, EU MSFD TGML, Korea NBLMP, MED DeFishGear, NOAA MDMAP, China MDMP, Indonesia SBDP, Japan DBDM, Viet Nam MAPPL).

Some programs include categories by usage such as fishing, packaging, and/or personal hygiene (GPLBP, EU OSPAR MML, China NCCMP, British BCP, Korea RA, African MLMM), which can possibly provide more information on the sources and causes. There are programs where materials and usages are listed together in the main categories (British BCP, GPLBP). GPLBP separates plastic fishing gears from the category of plastics to make recording them easier for surveyors. But for purposes of analysis, it includes plastic fishing gears under plastics. Another way to categorize debris is by its usage-related activities. For example, in the past, the ICC had categories indicating whether the item originated from smoking-related activities, dumping, shoreline or recreational activities, ocean or waterways activities, or medical or personal hygiene products. Nowadays, the categories are modified to separate the list of the most abundant items over decades out, which includes cigarette butts, food wrappers, bottle caps or lids, straws or stirrers, and more. In any categorization, it should be noted that an overlap between categories should be avoided and categories should be exclusive so that surveyors can reduce errors in reporting. In all monitoring, amounts and proportions of plastics are always presented as results.

To obtain more detailed information, each material or usage is often subcategorized into a list of specified items such as plastic water bottles, plastic detergent bottles, expanded polystyrene food containers, disposable knives and forks, fishing nets, and so on. It can render useful information that will help identify specific items or the most abundant items. The number of debris can range from 44 (Clean Swell) to 165 items (EU MSFD TGML). Such classification will provide the top 10 items in terms of number (Addamo et al., 2018; Roman et al., 2020).

A few monitoring programs have only surveyed selected items such as balloons (USA Virginia BL), cigarette butts (USA NOAA CLPP, Australia BYB, USA KAB CLPP), or disposable lighters (Japan DLP). It's usually because these items are very common and are considered to pose a serious environmental problem or because they are particularly useful when raising public awareness. These might serve as indicator items. While cigarette butts (USA KAB CLPP) and balloons (USA Virginia BL) are prime examples of such cases, disposable lighters (Japan DLP) can also be a specific monitoring target. In Fujieda et al. (2006), surveyors specifically surveyed disposable lighters and used the distributor's name or phone number marked on these lighters to trace the source. Monitoring specific items can be used to assess the efficiency of a policy on those items. It also has benefits to drastically reduce monitoring efforts. Lastly, even when all the debris get surveyed, there is still an opportunity to analyze particular items such as plastic beverage bottles (Ryan et al., 2019), single use plastics (Vlachogianni et al., 2020), and fishing gears (Simeonova and Chuturkova, 2020).

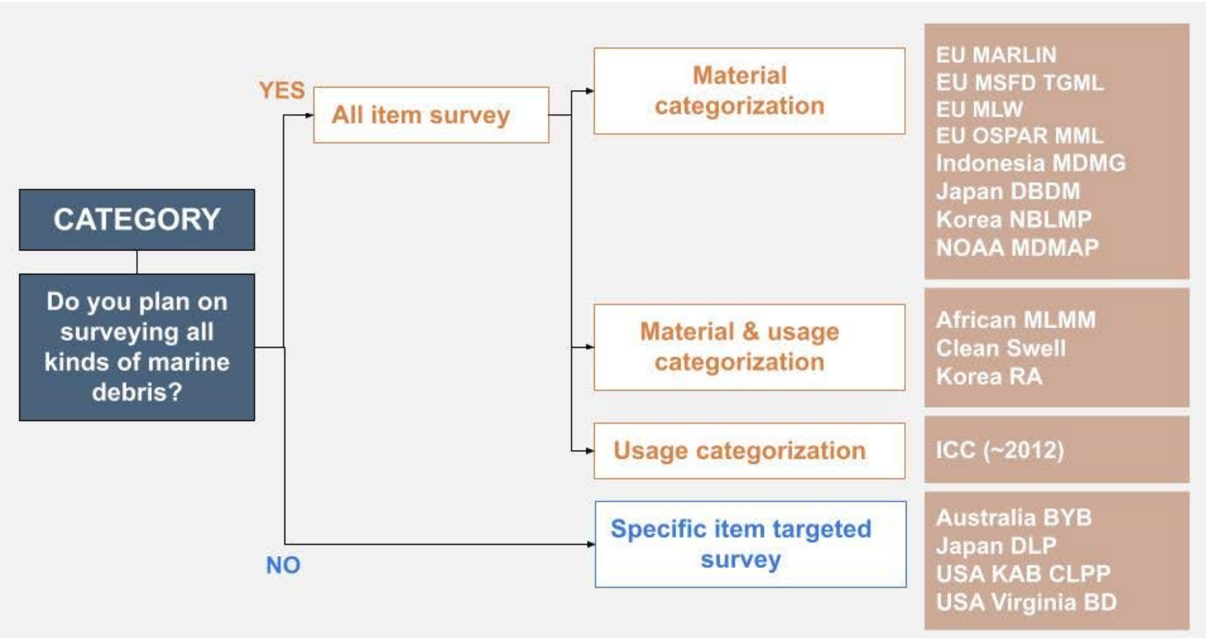


Figure 5. Decision tree on category and example. Table A5 in Appendix 1 presents the category of individual examples.

3.3 Scale

3.3.1 Spatial scale

[Key question] Do you plan on monitoring for domestic scale?

The scale of the monitoring program will depend on the objectives, the entity executing the program, budget, workforce, and other key considerations. The extent of spatial scale defined in GESAMP (2019) will be considered at the global, domestic, regional, and local scales (Figure 6). Encompassing a wider spatial scale will require more budget and workforce but will help determine marine debris pollution levels to a wide range of space and aid in identifying relatively more polluted areas. A domestic monitoring program is often conducted along the coastline of a particular economy and it provides a comprehensive understanding of the economy's pollution level that can lead to developing new policies. A regional monitoring program is conducted within a specific global region such as the Baltic (EU MARLIN), North East Atlantic (EU OSPAR MML), and Adriatic-Ionian macro

region (MED DeFishGear). Due to the transboundary nature of most marine debris, regional monitoring efforts can collect more information regarding marine debris affecting their region and also strengthen regional cooperation with neighboring countries. A local monitoring program is usually limited to the boundaries of a particular neighborhood, county or province. Localized monitoring efforts can easily be conducted with a relatively modest budget and a small workforce. In any case, there should be a justification for why a particular spatial scale was chosen. The monitoring results can be generalized only in the corresponding spatial scale (scale of inference).

The ICC is a global debris cleanup campaign utilizing a common data card by a worldwide network of volunteers and should not be recognized as a monitoring program to provide robust quantitative results. However, if repeated surveys are conducted at fixed survey sites using an ICC data card, this can also be a marine debris monitoring program. In the case of Chinese Taipei, the ICC data of 12 years has been utilized for developing policy measures and has been used for education and awareness raising among citizens (Walther et al., 2018). In the case of Korea, an attempt by Korea NBLMP has been made to produce comparable results by including items used in the ICC (Hong et al., 2014). With the absence of common monitoring methodologies and programs at a global level, ICC is playing an important role in collecting global data, if not monitoring.

Regional surveys are mainly conducted in the EU (EU MARLIN, EU OSPAR MML, etc.), because the Marine Strategy Framework Directive (MSFD) mandates the monitoring of marine debris. Local monitoring is likely to be very numerous and varied and finding appropriate local solutions are significant and essential. However, it is not covered in this document because there is insufficient information about it and it is difficult to aggregate it for comparison.

Strictly speaking, global marine debris monitoring is not yet available. It is very difficult to recruit surveyors from all over the world to repeatedly conduct surveys in designated areas with a unified method. Instead, volunteer cleanups and survey programs using mobile apps, e.g., Clean Swell, Litterati, and MDT, are conducted on a global scale. GPLBP led by CSIRO recruited and trained surveyors and conducted surveys on a global scale (Hardesty et al., 2018) If done repeatedly, GPLBP has the potential to be a truly global marine debris monitoring program.

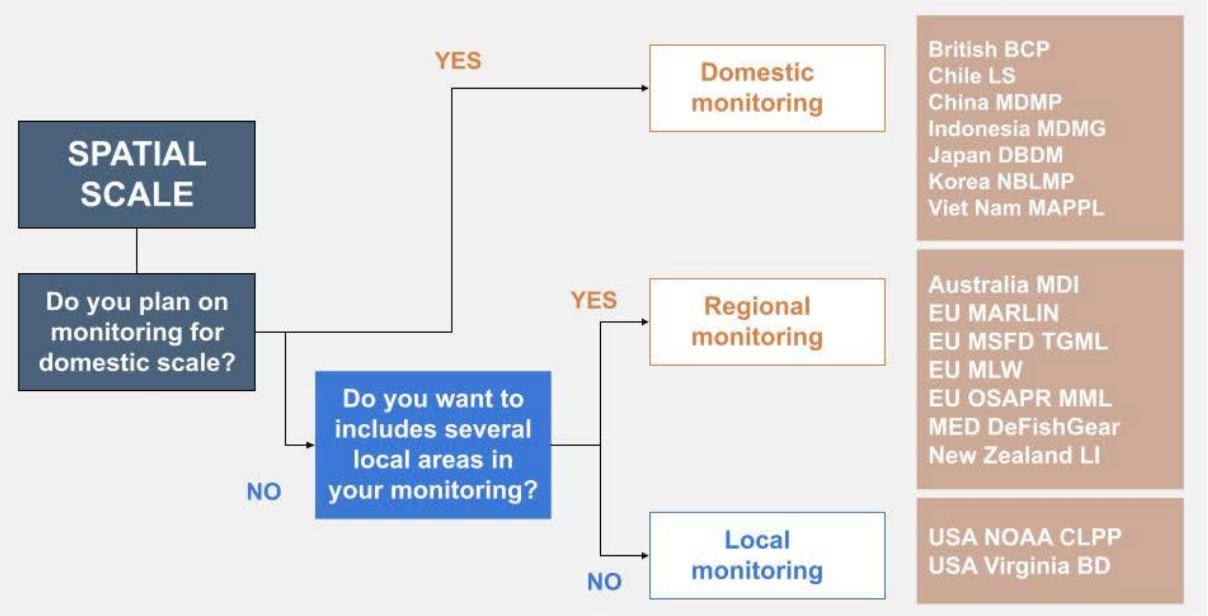


Figure 6. Decision tree on spatial scale and examples. Table A7 in Appendix 1 presents the spatial scale of individual examples.

3.3.2 Site selection

[Key question] Do you want to obtain representative data within a given spatial scale?

It is desirable to select representative survey sites in marine debris monitoring. Selecting a sufficient number of sites reflecting various environmental characteristics is a very difficult task. Therefore, many monitoring programs utilize 'spatial site selection', which arranges similar distances between survey sites. Selection of more representative survey sites considering environmental and social conditions using methods such as stratified sampling or stratified random sampling are rarely applied (Figure 7).

EU MARLIN and OSPAR MML serve as good examples of spatial site selection. These regional monitoring programs span several countries ensuring geographic representative distribution of survey sites among participating countries. In Japan DBDM, survey sites were selected among the three regions, Kuroshio, Tsushima, and Oyashio which are most affected by ocean currents.

Survey sites can be selected by using a stratified sampling method that considers the natural and social environmental conditions of the coast (GPLPB, Korea NBLMP). In GPLBP, a GIS program was used to randomly select survey sites based on the region's land use and distance between survey sites and population centers or major roads. In Korea NBLMP, new sites are being added to increase the representativeness based on the ratio of long-distance island coastlines to those of the mainland.

However, many monitoring programs are conducted on beaches that are simply available for surveys or those decided by survey participants. This is mainly due to the difficulties of site selection based on a statistical and structured method. Instead of monitoring the designated survey sites, the entity conducting the survey could arbitrarily select the survey sites. However, this approach limits the scale of inference to the surveyed site only. Therefore, some programs adopt a hybrid approach, where some sites are statistically determined for larger scales of inference and others are selected on-demand (NOAA MDMAP).

[Key question] How many survey sites should you select for the representative data within a given spatial scale?

Deciding on a number of survey sites will depend on the spatial scale and the variability of debris loads within that scale. While monitoring wider geographic areas will undoubtedly require more survey sites, monitoring changes over a long period of time will require continuous efforts, which is related to the intervals that surveys are conducted.

Number of sites and site characteristics are important when considering site selections. The number of sites can be determined prior to decision, or adjusted considering the sustainability of the program, which can be affected by required resources including budget and man power.

[Key question] What environmental conditions are needed to conduct shoreline monitoring?

It is desirable to randomly select the sites without considering environmental conditions, especially when representative monitoring data are needed. When selecting sites for a specific purpose, such as representing a sandy coast or representing a fishing area, sites that satisfy the environmental conditions for each must be selected. It would be preferable to determine site characteristics preceding site selection. By deciding the conditions of a survey site, the scope for site searching can be narrowed and the process of decision-making on site selection would be easier. In general, citizen science monitoring programs often include sandy or pebble beaches with gentle slope that are accessible to citizens as a criterion for selection.

When selecting survey sites multiple factors must be considered. These include, but not are limited to, the number of available surveyors and the accessibility of the survey site (COBSEA and CSIRO, 2022; Roman et al., 2020; Uhrin et al., 2020). Some programs even allow monitoring on not only sandy or pebble shores but also rocky shores (Korea NBLMP) and mangroves (African MLMM) and others authorize the surveyor to select and register survey sites as long as the monitoring protocol can be applied (NOAA MDMAP, Australia MDI). Two programs carry out stratified random site selections regardless of the physical or environmental conditions of the shoreline (GPLBP, Korea RA).

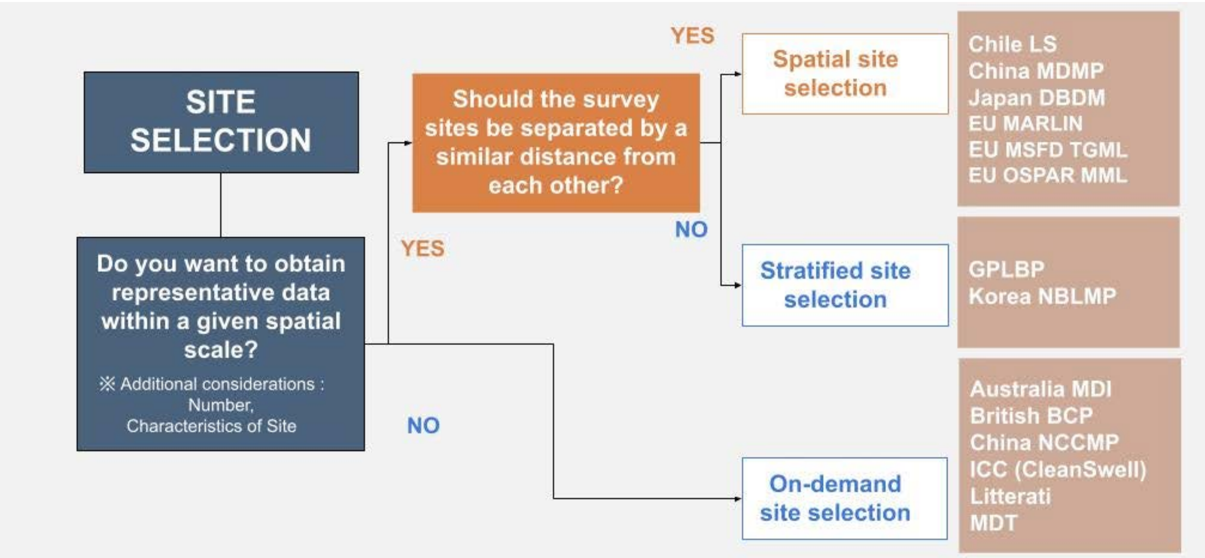


Figure 7. Decision tree on site selection and example. Table A7 in Appendix 1 presents the site selection of individual examples.

3.4 Data Collection

3.4.1 Training

[Key question] Do surveyors need training prior to conducting surveys?

Surveying marine debris at multiple sites at the same time may require surveyors to consist of members of various groups such as a university, NGOs, or economy agencies. When surveying with a diverse group, there may be different levels of knowledge that require prior training. Surveyors should first learn how to properly monitor marine debris and understand the importance of maintaining the same methodology when conducting surveys. Training on survey methods can be conducted using a manual, a simple online training program, or during an on-site training (Figure 8).

NOAA MDMAP and GPLBP share their monitoring toolboxes on its website with the public (Table A1). Any organization following the toolbox guidelines to conduct a survey may enter their results in the web database. EU OSPAR MML or New Zealand LI allows surveyors to participate in monitoring surveys as long as the manuals provided by EU OSPAR MML or New Zealand LI are used, but the host entity will decide whether or not to allow the entry of results. Instead of simply providing manuals, many domestic monitoring programs provide educational training for surveyors. At a minimum, field survey leaders are required to complete a training. Domestic monitoring programs, e.g., Korea NLBMP, China MDMP, Japan DBDM, are conducted economywide over a long period of time with the purpose of using the results to develop policies. Therefore, these programs often include managing data quality as well. For more scientific precision, additional or repetitive training will be required.

To encourage and aid the public in participating in monitoring surveys, online and offline guidelines, education, and training will be needed. Training can be easily conducted using videos or manuals, or they can be provided by the organizing entity specifically tailored for its prospective surveyors. However, monitoring programs using a smartphone seldom provide separate training opportunities. There is a significant issue with measuring marine debris from apps if the app does not record the survey effort. This data is much more complex to analyze and is difficult to use as a monitoring tool.

In principle, training depends on the type of data and the complexity of the protocol. However, practically, when designing a monitoring program, the methodology may need to be adjusted depending on what level of training can be provided.

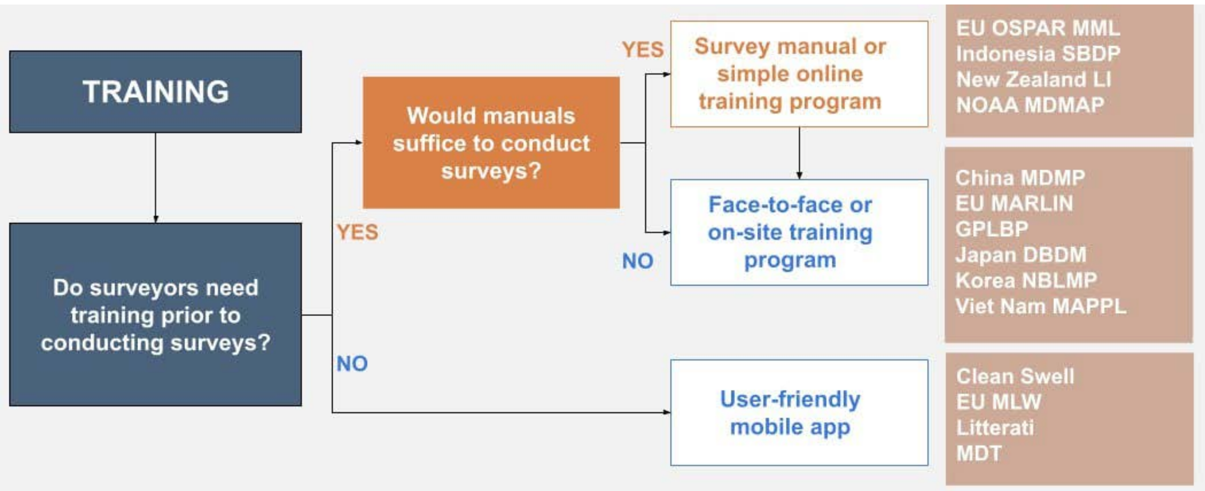


Figure 8. Decision tree on training and example. Table A8 in Appendix 1 presents the training method of individual examples.

3.4.2 Interval

[Key question] Are you looking to understand the seasonal impact on marine debris?

Monitoring interval depends on the objective of the monitoring program, budget, workforce, environmental factors such as weather and climate, and accumulative pattern. Frequent monitoring will be particularly helpful when measuring the variability of marine debris (GESAMP, 2019) over a long period of time, and this will in turn help realize the changes in pollution levels. However, frequent monitoring will require a larger workforce and more effort. The monitoring interval ranges from once a year to daily (Figure 9).

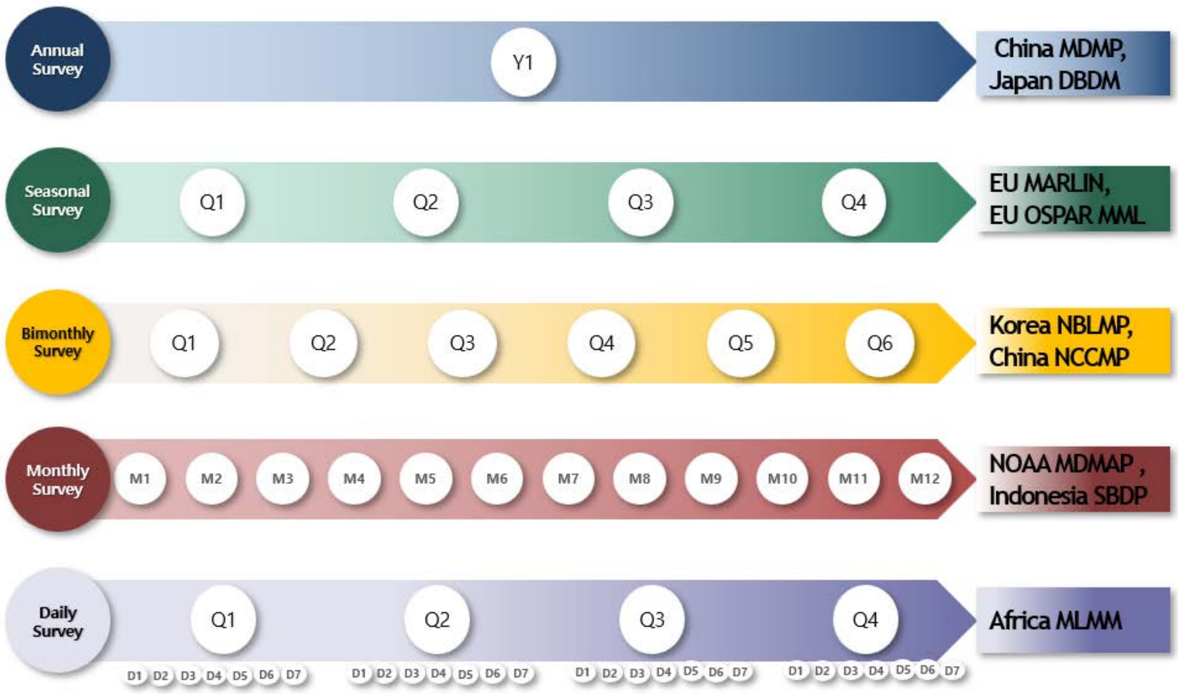


Figure 9. Examples of the frequency of sampling in various monitoring programs.

If the survey cycle can be adjusted to four seasons, four surveys may be conducted, e.g., EU OSPAR MML, but if conducting a survey in the winter is not possible due to inclement weather conditions, three season surveys may also be conducted, e.g., EU MARLIN. If more frequent surveys can be conducted, it may be performed monthly or bi-monthly, e.g., NOAA MDMAP or Korea NBLMP. If the influence of the monsoon is important, two surveys before and after the monsoon will reflect seasonal effects, e.g., GPLBP. An annual survey, e.g., China MDMP, or biannual survey, e.g., Viet Nam MAPPL, can also be conducted to determine annual fluctuation of debris abundance regardless of the season. As for daily surveys conducted to understand debris accumulation (number and weight per meter per day), the African MLMM recommends a predetermined 250-500 m of beach for seven to ten consecutive days. In many cases, the interval is not kept constant and is carried out according to the convenience of the surveyors (Australia MDI, MDT) (Figure 10).

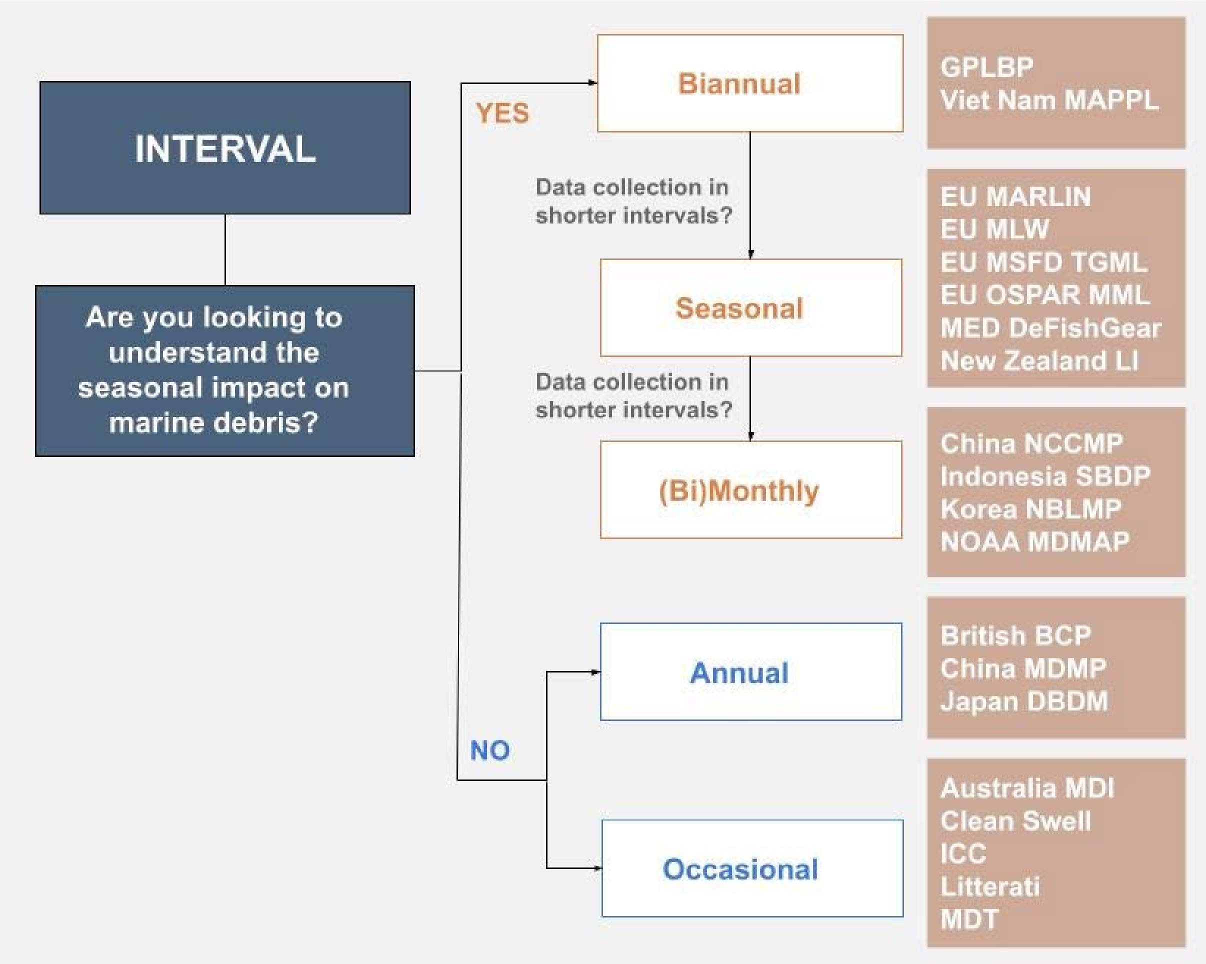


Figure 10. Decision tree on interval and example. Table A8 in Appendix 1 presents the interval of individual examples.

3.5 Measurement

3.5.1 Standing stock and accumulation survey

[Key question] Do you plan on collecting and measuring debris?

In monitoring programs, the question of whether or not to clean up after a survey is sometimes an important issue. According to Cheshire et al. (2009), cleaning up is always required after a survey in order to measure the amount of debris that has entered the beach for a certain period of time and this is defined as an ‘accumulation rate survey’. The initial baseline survey is an estimate of the ‘standing stock’ and repeated surveys with consequent cleaning at regular intervals are defined as an ‘accumulation survey’ to measure the flux of debris onto the shoreline over time (Barnardo and Ribbink, 2020; GESAMP, 2019). European Commission (Hanke et al., 2013) indicates that accumulation or loading rates reflect a balance between input from land and sea and output through washout, cleanup, fragmentation and burial. Seasonal, bi-monthly, or monthly surveys may not accurately show accumulation rates, fluxes, or loads with or without subsequent cleanup, but consistent surveys allow for inferring patterns of increasing or decreasing of debris over time (Cheshire et al., 2009; GESAMP, 2019; Hanke et al., 2013; Lippiatt et al., 2013). African MLMM describes the details of how to remove the marine debris after the initial baseline survey and how to estimate daily accumulation rate for seven to ten days with three-month intervals. However, it should be noted that since the daily accumulation rate of marine debris is much higher than the monthly accumulation rate, using monthly measurements to estimate the amount of marine debris is likely to be underestimated (Eriksson et al., 2013; Smith and Markic, 2013). A few monitoring programs mandate no cleaning (GPLBP, Korea RA) because they estimate the snapshot of marine debris when surveyors visit the sites (Figure 11).

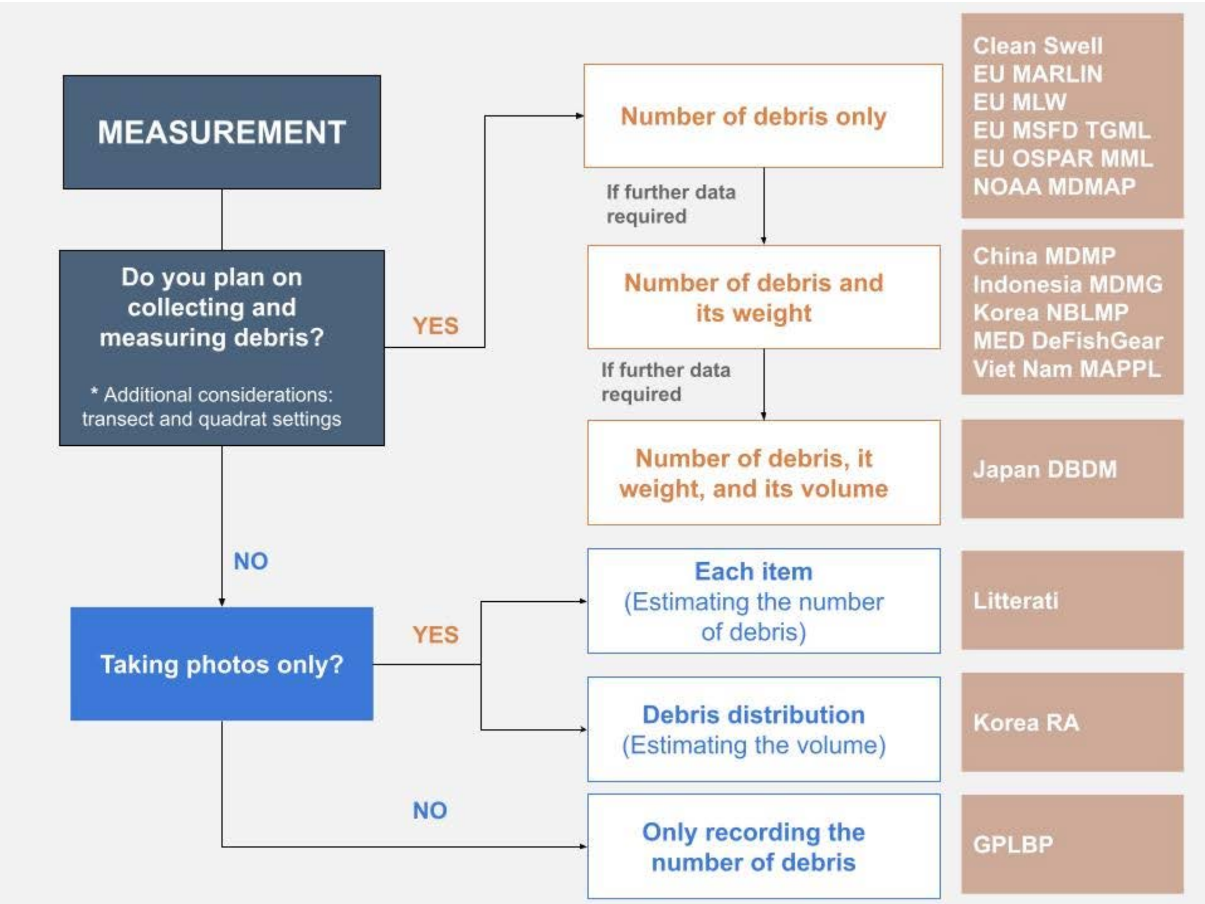


Figure 11. Decision tree on measurement and examples. Table A8 in Appendix 1 presents the measurement of individual examples.

3.5.2 Survey location

[Key question] Where on the beach should you survey?

Within a survey site, survey areas can be parallel or perpendicular to the shoreline. Although it would be ideal to select a location that is representative of the distribution of debris on the shore, there is no standard length in terms of how long the area should parallel the shoreline. The most commonly used length is 100 m along the shoreline. When examining mega debris, the shoreline can be as long as 1 km (EU Marlin, EU OSPAR MML). African MLMM recommends 100 m for standing stock survey and 250~500 m for accumulation survey. In the case of Indonesia SBDP, three sets of 150 m are selected. Korea NBLMP uses a length of 100 m and the same location is surveyed repeatedly.

Most of the surveys perpendicular to the shoreline are conducted from the water edge to the vegetation zone or to the barrier on land. In the case of GPLBP and MDMAP, it is recommended to extend the survey 2 m further from the vegetation zone or other permeable barrier in the land direction. This is because the vegetation zone acts as a trap or sink catching the debris, and if this vegetation zone is not surveyed, important estimates of debris pollution may be missed. In Indonesia SBDP, as an exception, an area of 450 m with 3 m-width along the stranded line is surveyed. However, the stranded line is more likely to show a higher level of pollution than the entire debris, which possibly causes overestimates.

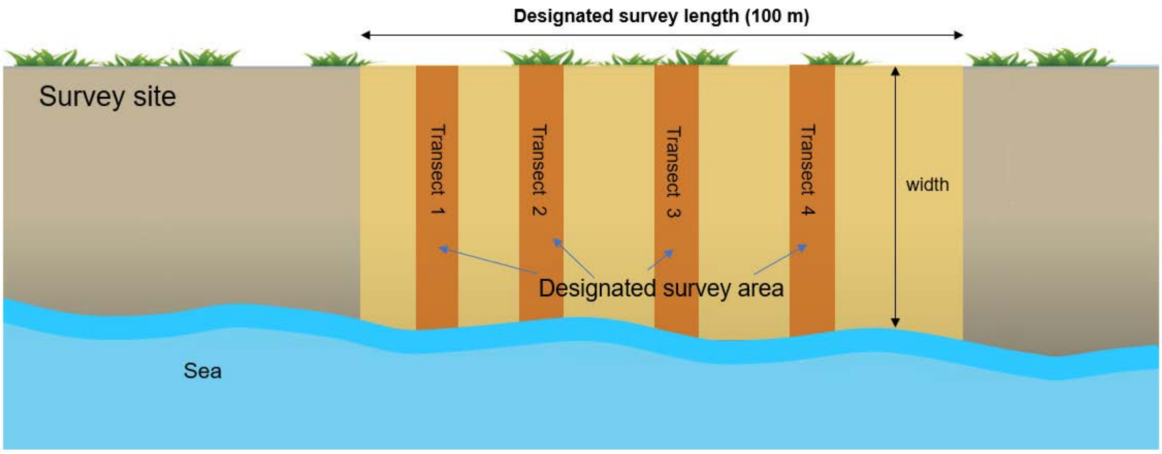
[Key question] Within a beach, what are the dimensions (resolution) of the survey area?

Survey areas are designated within a monitoring site and demarcated in terms of length, e.g., 100 m or 500 m. There are two ways to select survey areas: the entire area or areas within the selected transect(s) or quadrat(s) (Figure 12). Monitoring areas within the transects or quadrats enable us to obtain replicates that reflect the heterogeneity of debris within a site (Hardesty et al., 2017). Delimiting transects on a site are usually perpendicular (MDMAP) or parallel to the shoreline (Indonesia SBDP). The number of subsampled transects or quadrats (Figure 12) varies depending on monitoring objectives and the distribution of debris because shoreline debris are generally distributed unevenly on a fine spatial and temporal scale (Lippiatt et al., 2013). If more representative data for the survey site are wanted, more transects or quadrats will be necessary. Multiple measurements from one survey site will help to generate the mean and the variance, which strengthens the statistical power of the survey results (Lippiatt et al., 2013). However, special caution should be paid because a specific transect parallel to the shoreline, such as high strandline, may reflect the most accumulated area within the survey site (Indonesia SBDP). On the other hand, if randomly selected quadrats are deviated from (outside of) the strandline, the survey result may not reflect the accurate level of debris found at the survey site.

If a transect or quadrat is installed within a certain length of shoreline, it can be ambiguous to report debris quantity per meter or per square meter. For SDG 14.1 reporting, UNEP (2021) proposed shoreline debris count per km^2 of shoreline as an agreed indicator. However, debris is generally washed ashore along a linear front and deposited in a series of strandlines that run parallel to the shoreline. So GESAMP (2019), Ryan et al. (2020) and Uhrin et al. (2022) recommend that measurement of surveys be expressed per unit length (m) of shoreline and integrated across all strandlines from the waters edge to the back barrier of the beach.

[Key question] What kind of search pattern within the survey area should be applied to achieve consistent effort?

Most macro debris monitoring programs guide collecting all debris larger than 25 mm from the location. In some cases, a paper measure is provided along with a manual or a survey card so that the size can be measured in the field. African MLMM suggests a pattern of walking through the location or area under to collect all items and that at least one person (called ‘The Sweeper’) should pick up again behind the others so that no debris items are missed. On the other hand, in the case of GPLBP, there is a characteristic that only records visible debris at eye level and does not pick them up.



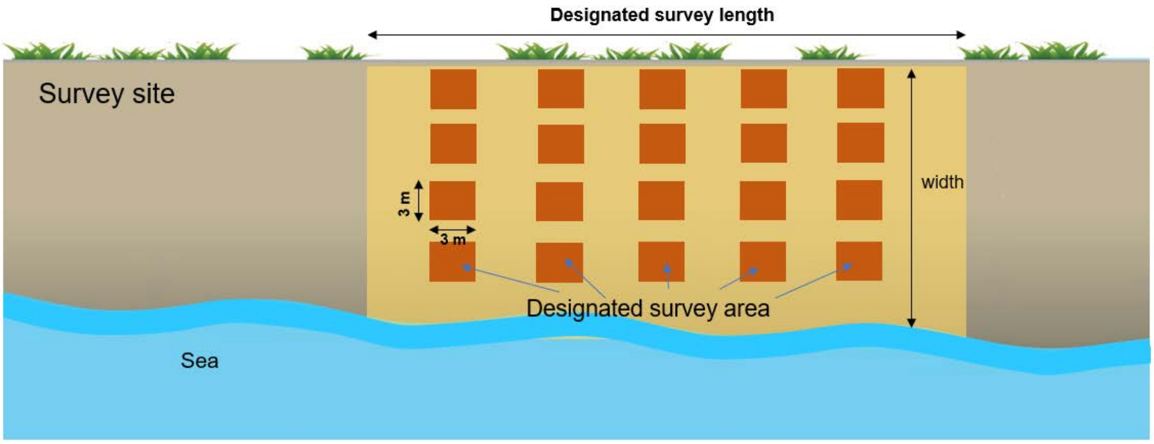


Figure 12. Example of a designated survey area at a survey site: selection of transects (a) or quadrats (b)

3.5.3 Unit

[Key question] Do you want to measure the number or weight of marine debris quantity?

The abundance of marine debris can be expressed in terms of number (count), mass (weight), or volume per linear meter or square meter depending on the objectives and survey methods. Measurement by number is feasible and is used in most monitoring programs. Number of items per length of shoreline are appropriate to inform policy makers to reduce total debris abundance or particularly concerned items. These items (e.g., EPS buoys, ropes) are likely to result in high abundance when there are many small items fragmented due to harsh environmental conditions at shoreline (Hong et al., 2014).

Measurement by weight is less common than measurement by count. Measuring by weight can be difficult when the debris is wet, buried, full of contents (e.g., drink bottle), or too heavy or too light to be measured by scale. However, the weight of debris can provide a good estimate of the necessary resources needed to remove and dispose of the debris and can be used to estimate mass balance between inflow and outflow of marine debris for management purposes at the domestic level (Bai et al., 2018; Jang et al., 2014). It should be noted that a very small number of heavy debris can occupy a large proportion in the weight and may affect the overall result (Smith and Turrell, 2021). To measure individual items, African MLMM guides to collect all debris, remove the contents, wash and dry them well, and then record the weight. However, following this method can be challenging because it requires more time and more effort. In some cases, each item is not weighed separately, but only by material (China MDMP, EU MSFD TGML, Korea NBLMP).

In the case of volume, it is measured by filling a bag with particular volume size or by visual estimation but is difficult to measure accurately (Japan DLP, Korea RA, UNEP/IOC GSMML). Since each unit has a different meaning, it would be ideal if all of them could be measured. When considering the objective of a policy development based on monitoring data, using the measurement of number of items as a standard element and additionally using measurement of weight is recommended (GESAMP, 2019; Ryan et al., 2020; Uhrin et al., 2022).

Recording both the main categories (materials or usages) and subcategories (items) as numbers is the most common case. Measurement by weight only for the main categories are more often than each item. Also, when measurement units are different, results cannot be compared.

On the other hand, in the case of Clean Swell, if surveyor inputs the number, there is a function that automatically converts it to weight. Since it is not an exact measurement, it is difficult to recommend automatic weight conversion.

Surveys that do not collect debris can be divided into those that only take photographs and those that only record the type of debris (Figure 11). For example, Litterati takes individual photos of the debris to determine the number of each type of debris. In Korea RA, the distribution of shoreline debris is photographed, and the amount of debris is estimated based on the volume (Table A2). In GPLBP, debris is not collected but the number of each type of debris is recorded while closely observing them within a designated area.

[Key question] What equipment do you need for monitoring marine debris and data recording?

For most monitoring programs, surveyors need a data card or data sheet, writing materials, a camera, mobile phone, measuring tape, trash bags, scale, and gloves. When using paper data cards, data collection can take up a considerable amount of time mainly due to the need for gathering the recorded data for entry into a database or spreadsheet. If there is an online database available for surveyors to enter their data, data collection will be much easier. Also, using mobile apps can be convenient because data can be uploaded in real time.

3.6 Data Management

3.6.1 Quality management

[Key question] How will you be managing the quality of your data?

Quality management provides strategies for ensuring the accuracy of data acquisition, preventing potential errors from all procedures of monitoring, and providing confidence of survey results associated with monitoring objectives (Galgani et al., 2013). If one of the monitoring objectives is to evaluate the temporal variation or effectiveness of a specific policy, high-quality data is required and the methodology for this needs to be well-organized.

In many cases shoreline macro debris monitoring programs are not clearly defined. The most common method for quality management is to provide manuals on survey methods but the level of detail varies from simple guidelines to detailed instructions (e.g., New Zealand LI). Proper monitoring methods can only be undertaken when surveyors easily understand the illustrations and pictorial guides in the manuals (Burgess et al., 2021; Jambeck et al., 2015; OSPAR commission, 2010).

In order to ensure that surveyors abide by the guidelines, it is necessary to provide educational training instead of solely providing a manual. Educational training for surveyors is often provided by global monitoring programs led by research institutes like GPLBP or government-led monitoring programs that conduct monitoring efforts both domestically and regionally, e.g., China MDMP, EU MARLIN, Japan DBDM. Target marine debris must not be omitted within the designated survey area or shoreline, and surveyors must be familiarized with classification categories to collect reliable data. In addition, particular attention must be given to recorded data because errors that inadvertently occur will affect data accuracy. Thus, repeatedly providing training opportunities will be necessary to maintain survey consistency.

Another method to ensure quality data is to conduct joint surveys. Comparison in data records between a survey conducted by citizen scientists and a subsequent survey by experts can be a helpful process to ensure quality management. Lippiatt et al. (2013) recommends the second surveyor to evaluate 20% of the total number of transects sampled per site and minimizing the discrepancy between surveyors and experts. For Korea NBLMP, monitoring experts have visited every Korean beach by taking turns and conducted surveys together. This also helped maintain consistency across multiple surveys by different surveyors in different sites.

A more practical approach is made in African MLMM, in which sampling protocols are slightly modified and applied into three approaches such as 'gold, silver, and bronze'. In each approach, survey requirements are different so that data management will be followed by monitoring standards. It will make surveyors easier to follow the protocols and meet the requirements. As a result, data will be more reliable and comparable with each standard.

When conducting extensive monitoring, ordinary citizens are often trained as citizen scientists. Citizen science provides an important contribution to monitoring efforts (Hidalgo-Ruz and Thiel, 2015) and there are many levels of citizen science (Barnardo and Ribbink, 2020; Thiel et al., 2017; van der Velde et al., 2017). Van der Velde et al. (2017) found that kids are the next best to professional trained surveyors. Maintaining a certain number of surveyors is often an important factor because the number of surveyors, their respective experiences, and the condition of the survey sites can affect survey results (Uhrin et al., 2020; Van der Velde et al., 2017).

Among the cases of using mobile apps, there that provides quality assurance (QA) and quality control (QC) processes for management. New Zealand LI uses only data submitted by citizen scientists who have received official training and standardized equipment for QA as official data. There is a process of checking input errors using the app even after data submission, and the error rate is calculated by resurveying in 10% of the survey areas.

However, if raising public awareness is an important objective of the monitoring program, it may be a reasonable option to compromise on data accuracy in order to garner more public participation (Figure 13).

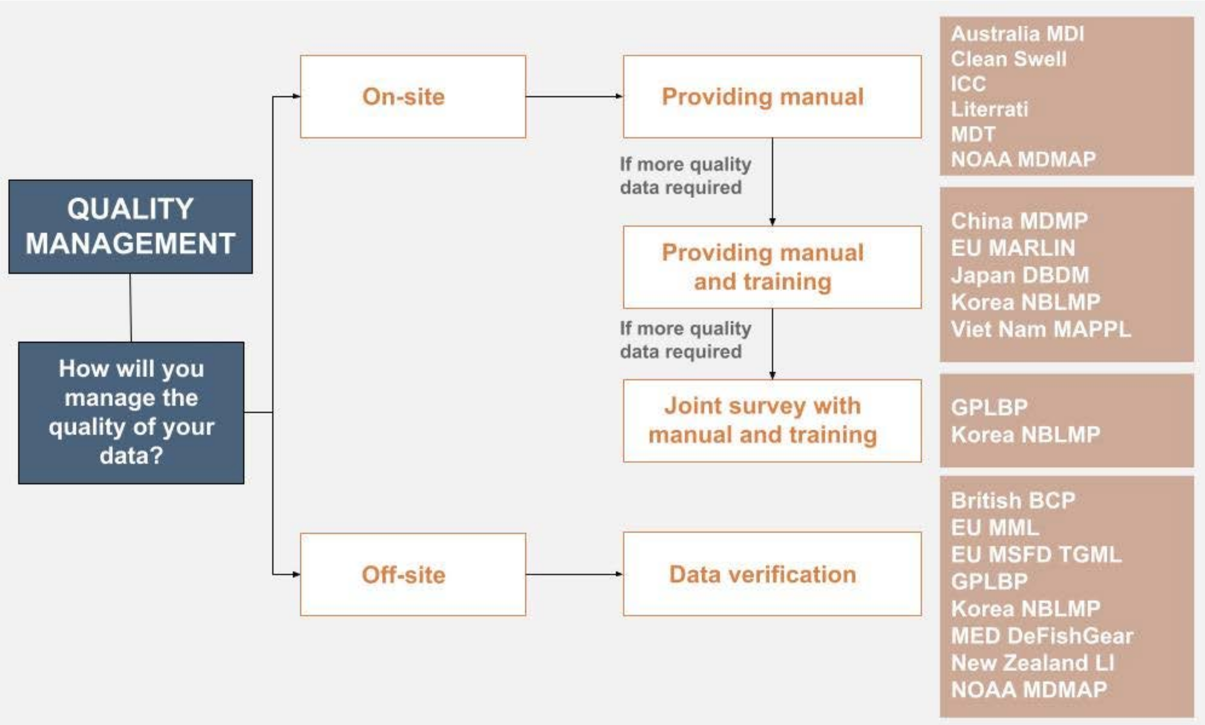


Figure 13. Decision tree on data quality management and example. Table A9 in Appendix 1 presents the quality management of individual examples.

3.6.2 Database

[Key question] Do you plan on creating a separate database for your monitoring program?

Upon completion of a survey, the dataset collected ideally is stored in one location. One of the common ways is to enter the raw data into flat files such as Microsoft Excel or Google Sheet. Some monitoring programs have their own databases to store and analyze data.

Recently, web databases are increasingly used, and large-scale monitoring programs have been operating their own databases as well, e.g., GPLBP, China MDMP, Korea NBLMP, EU MARLIN. When it is difficult to create a new database, an existing system can be used. There are two types of existing systems: a closed system requiring approval before entering the data, and an open system where anyone can enter data. EU MLW, NOAA MDMAP and New Zealand LI are web databases where anyone can view the results, but prior approval from the administrator is required to enter the data. This helps ensure that people do not enter erroneous data.

Australia MDI, Clean Swell, and MDT, which are completely open systems, allow anyone to enter data and inquire results by simply going through the membership registration process. In particular, MDT is a very useful web database that can be utilized by more than 70 programs that are carried out globally. Among the existing programs, users can select the one that suits their needs.

Survey results are often recorded using a paper data card, but recently, there have been an increasing number of monitoring programs using web or mobile apps for data entries. Using a web data entry portal or an app has an advantage of automatically compiling and maintaining information. However, it is useful to include supplementary measures, such as taking photographs that will provide evidence of records obtained in the field even when a web portal or an app is used. In the case of Korea NBLMP, while a web database has been established, a paper data card is currently being used despite having developed a mobile app. This additional measure was implemented most likely to minimize errors that often occur when entering data using a computer or an app by comparison between data entry and data card (Figure 14).

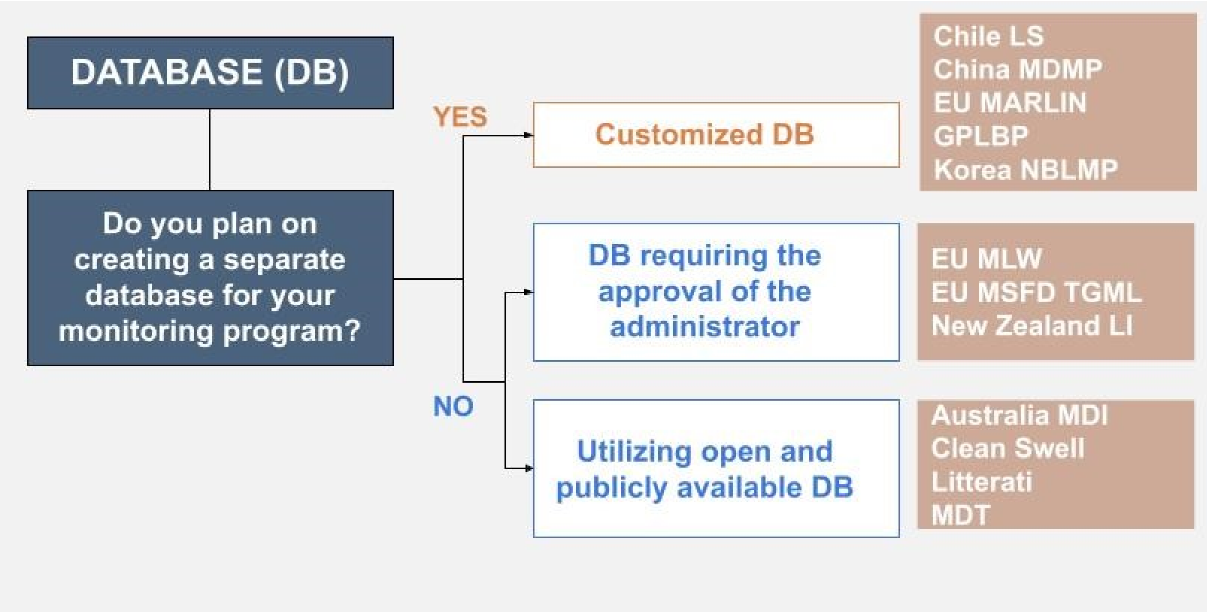


Figure 14. Decision tree on database and example. Table A9 in Appendix 1 presents the database of individual examples.

3.6.3 Data analysis

[Key question] Are simple descriptive statistics sufficient to achieve your goals and objectives?

When analyzing data obtained from shoreline macro debris monitoring, the most basic data obtained is abundance which is expressed as number of debris per length or area. Abundance of plastics and its proportion are always included in the main result. Abundant items in number receive attention. Average abundance over time or space can be obtained by descriptive analysis.

Using an open database system is the easiest method to display such data results. When using a mobile app, metadata, including survey locations and duration, along with a total number of surveyed debris and the most abundant debris category, will automatically be generated upon data entry (Clean Swell, Litterati, MDT, NOAA MDMAP). Some mobile apps will even provide an estimated mass of debris and comparable regional graphs (Clean Swell). However, in order for the public to freely enter and extract results of the survey in various forms for different purposes, there must be a well-established database that can support such analyses and display.

To obtain detailed analysis result without a professional workforce, one can consider the program that provides brief analyses of descriptive summary like average number, weight and composition of debris surveyed, such as EU MLW or New Zealand LI. The websites of these two programs schematically illustrate the analyses of data results through various tables, figures, and maps. Prior to entering the data, an approval by the program's administrator will be required along with the adherence to the program's research methodology.

If an in-depth analysis is needed, an available workforce with considerable expertise is required. Domestic, regional, or global monitoring programs led by governments or research institutes are often developed by experts who also analyze results, e.g., EU MARLIN, EU OSPAR MML, GPLBP, Japan DBDM and Korea NBLMP. For instance, NOAA MDMAP automatically summarizes data into graphs of composition, items per 100 m, and selected geographical scales (the survey, all surveys at a site, or all sites from a user selected group), but a more sophisticated analysis would require a specialist (Figure 15).

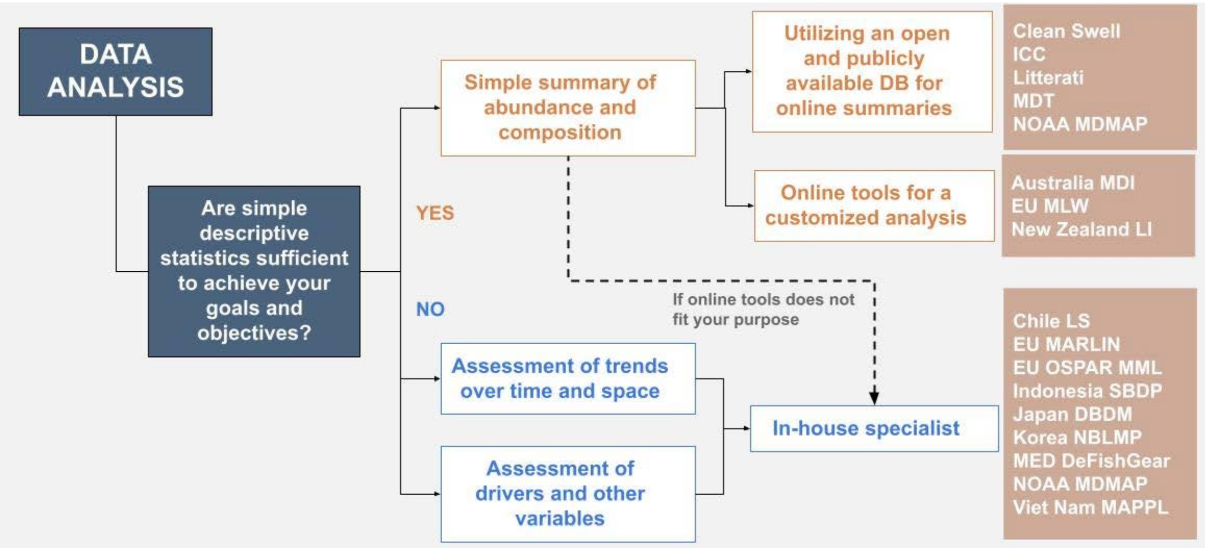


Figure 15. Decision tree on data analysis and example programs. Table A9 in Appendix 1 presents the data analysis of individual examples.

[Key question] How can you use the monitoring data?

It is very important to properly utilize the data generated from a monitoring survey, especially when volunteers or public resources are being used, so that valuable resources and hard work will not be in vain. Moreover, it is necessary to evaluate whether the data are being used to achieve the objectives of the monitoring program. Monitoring specific items such as cigarette butts and balloons are useful when their objective is to inform the public regarding the seriousness of the pollution caused by these specific items (Register, 2021).

In Korea NBLMP, it was found that the most commonly observed beach debris was expanded polystyrene buoys from oyster farms (Hong et al., 2014), and these results were used to develop and implement preventive policies (Hong et al., 2018). Shoreline marine debris monitoring results in the USA and Australia have also shown that beverage container deposit legislation affects the amount of debris found along shorelines (Schuyler et al., 2018a). Harris et al. (2021) revealed that the extended producer responsibility did not contribute to reducing the amount of marine plastics by using the ICC and NOAA MDMAP data. In Chinese Taipei, by analyzing the results produced from 12 years of ICC, a proposal was made to strengthen regulations on disposable items and discarded fishing gear (Walther et al., 2018). Monitoring results of EU MARLIN or OSPAR MML are expected to be used as an indicator to evaluate whether ‘Good Environmental Status (GES)’ has been reached, according to MSFD. EU Member States set the threshold of shoreline debris to be 20 items per 100 m in 2020 (Hanke et al., 2019; Van Loon et al., 2020).

4 CASE STUDIES

Thirty-one shoreline monitoring programs or methodologies were reviewed in the context of 5 classification categories and 11 criteria (Table 4 and Figure 1). Among them, relevant monitoring program examples were selected according to the decision tree for each of the 11 criteria. Based on the above criteria and examples, an automated decision tree was created using Google Forms Choosing a Marine Debris Monitoring Program? (google.com)[3]. Following the prompts for each criterion in order, users can select from multiple options or provide alternatives that will best reflect their desired monitoring scheme. Certain steps may require revisions or modifications. This information and the Google Form were shared during a virtual workshop on June 22.

After the workshop, Peru and Chile submitted an application for a consultation meeting by filling out the Google Forms. The purpose of these consultation meetings with interested member economies was to provide relevant advice on developing a marine debris monitoring program and introduce the best monitoring protocol for the economy by providing applicable references. The consultations would help tailor the needs of the member economies and find a suitable marine debris monitoring program. The meeting consisted of explaining the purpose of the consultation, sharing the current status and plans of the member economy for monitoring marine debris, reviewing the results of the Google Form, introducing the most appropriate monitoring methodology, and discussing possible solutions for monitoring challenges.

4.1 Peru

After the virtual workshop on June 22, a Google Form response from Peru was received (Table 5). The consultation meeting with Peru took place on July 11, 2022 (10:00~12:00, KST). The meeting was attended by Dr. Jongmyoung Lee and other researchers of OSEAN as consultants and the respondent, Dr. Sara Purca of IMARPE (Instituto del Mar del Perú) attended on behalf of the Peruvian economy. Below is a summary of finding the optimal monitoring methodology by synthesizing Table 4, questions and answers, and discussions during the meeting.

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[3] The Google Form was provided to the participants on June 22, 2022. https://docs.google.com/forms/d/e/1FAIpQLSf4chtbaTdJnNKRHTARKFsy8Q1Vham1OiH8mov4OzRe-ot3Vg/viewform

Table 5. Google Form result from Peru

Criteria	Selections of Peru
1. **Goals and Objectives**: What are the objectives of your monitoring program? (You may select multiple answers if necessary)	Identifying status or level of pollution (Chile LS, China MDMP, Korea RA)
	Conducting a spatial assessment of marine debris (China MDMP, GPLBP, Japan DBDM)
2. **Size:** What target size will you be monitoring?	Debris larger than 5 mm (China MDMP, New Zealand LI)
3. **Category**: Will you be surveying all types of marine debris or only specific target items? If you plan on surveying all of the debris, will you be categorizing by material or by source?	All item survey - material categorization (EU MARLIN, EU MLW, EU MSFD TGML, EU OSPAR MML, Indonesia MDMG, Japan DBDM, Korea NBLMP, NOAA MDMAP)
4. **Spatial Scale**: Will you be monitoring shoreline debris locally or nationally? What is your geographical scope?	Regional monitoring (Australia MDI, EU MARLIN, EU MLW, EU MSFD TGML, EU OSPAR MML, MED DeFishGear, New Zealand LI)
5. **Site Selection**: What standards will you use when selecting a monitoring location? Do you plan on selecting a site based on a structured methodology?	Spatial site selection (Chile LS, China MDMP, EU MARLIN, EU MSFD TGML, EU OSPAR MML, Japan DBDM)
6. **Training**: How will you recruit and train surveyors? Do surveyors need training prior to conducting surveys?	Face-to-face or on-site training program (China MDMP, EU MARLIN, GPLBP, Japan DBDM, Korea NBLMP, Viet Nam MAPPL)
7. **Interval**: How often will you be monitoring? Are you looking to understand the seasonal impact on marine debris?	Seasonal (EU MARLIN, EU MLW, EU MSFD TGML, EU OSPAR MML, MED DeFishGear, New Zealand LI)
8. **Measurement**: What will you be measuring when monitoring? Do you plan on collecting and measuring debris?	Collect and measure the number of debris and its weight (China MDMP, Indonesia MDMG, Korea NBLMP, MED DeFishGear, Viet Nam MAPPL)
9. **Quality management**: How will you be managing the quality of your data?	On-site: Providing manual and training (China MDMP, EU MARLIN, Japan DBDM, Korea NBLMP, Viet Nam MAPPL)
10. **Database**: Where will you be submitting your monitoring data? Do you plan on creating a separate database for your monitoring program?	DB requiring the approval of the administrator (EU MLW, EU MSFD TGML, New Zealand LI)
11. **Data Analysis**: How will you be analyzing your monitoring data? What analysis is needed to achieve your goals and objectives?	In-house specialist (Chile LS, EU MARLIN, EU OSPAR MML, Indonesia SBDP, Japan DBDM, Korea NBLMP, MED DeFishGear, NOAA MDMAP, Viet Nam MAPPL)

[Status of marine debris monitoring] Is there an ongoing or planned marine debris monitoring program in Peru?

Peru's marine debris monitoring program started in 2020 but has since stopped due to the pandemic. The program was applied to 11 sites near coastal areas where IMARPE laboratories have been set up. Titicaca Lake was among one of the 11 sites. The objective the program was also to see the relationship between marine debris problems and nearby cities.

Currently, there are two proposals from foreign institutions for developing a marine debris monitoring program in Peru. The first proposal is from the University of Exeter, UK and the second is from the International Atomic Energy Agency (IAEA). The first proposal focuses on reducing marine debris along the Eastern Pacific Ocean, but the coastal areas along the Eastern Pacific Ocean include not just Peru but also Ecuador and Chile. It focuses a lot on fisheries and fishing related problems such as microplastic pollution and other related matters. The other proposal named 'Marine Stressor into the Latin American and Caribbean Seas' from IAEA focuses on standardizing microplastic analyses and observing the trends of microplastics along the Peruvian ocean. It emphasizes microplastic pollution in the ocean, beaches, water columns and major fishing resources. Both programs are supported by the Peruvian government.

[Confirming the results of Google Form questionnaire] What is the most appropriate monitoring methodology for Peru?

The consultants reviewed the Google Form response to find the most appropriate monitoring methodology. Peru selected its target debris as anything larger than 5 mm and deemed it to be the most important factor when choosing a monitoring methodology. However, most monitoring programs set target sizes to be at least 25 mm, and the only programs that set target sizes to at least 5 mm were China MDMP and New Zealand LI. While China MDMP is a program that can only take place in China, New Zealand LI can be used by participants from all over the world. New Zealand LI is a recommendable monitoring methodology for those who want to carry out material-based all item surveys including count and weight measurement. New Zealand LI publishes methodologies and manuals on its website and provides a DB requiring the approval of an administrator. For these reasons, the consultants preliminarily chose New Zealand LI as the most suitable monitoring program for Peru.

[Introduction to the most appropriate monitoring methodology] How to develop a marine debris monitoring program in Peru?

During the consultation, the monitoring methodology of New Zealand LI was introduced. New Zealand LI's website provides a detailed overview and a methodology of beach debris monitoring with a variety of forms and guides. This includes setting up survey areas, collecting and recording the amount of debris by type, as well as highly advanced quality management. New Zealand LI's DB also provides tooltips in data entry fields to prevent errors that may occur when the surveyor enters the data. The web app caches allow data to be stored temporarily even if the mobile device's battery is drained or if the signal is lost. It requires that 10% of the total survey area is re-examined by a designated staff to ensure that all the debris on the beach is collected and accurately classified and recorded. Its safety management guidelines also provide tips for handling hazardous debris such as asbestos, sharp objects and sanitary items, methods, and forms for establishing a health and safety management plan, and a risk assessment checklist. Three to twelve people are needed to conduct four surveys a year in New Zealand LI, which is in line with Peru’s needs.

[Discussing the resolution of monitoring challenges] What are the challenges for developing and implementing a marine debris monitoring program in Peru?

Currently, the biggest challenge in marine debris monitoring is the pandemic. The government's policy prohibited more than 10 people from gathering on the beach. From 2020 to 2021, only four or fewer gatherings were allowed which meant led to four people, including the leader, conducting field surveys, but it was very difficult to do the survey with such a small number of people.

The most commonly found trash on Peruvian beaches is hard plastic, and the second is fiber. In particular, fiber accounts for a significant proportion of the number and weight, and there is a lack of information about their origins. The fiber commonly found on the beach is mainly nylon, which is believed to have originated from clothing due to its variety of colors. Information is also needed on how fiber debris is generated and managed and how it is introduced into the marine environment.

[Finalizing consultation] What will be the most appropriate methodology for Peru?

The Peruvian member economy was advised to choose New Zealand LI and to contact its program operator (Sustainable Coastlines) for more information. Sustainable Coastlines, Dr. Purca and the researchers of IMARPE, a research institute preparing a marine debris monitoring program, will be able to provide in-house specialists for quality management and data analysis.

4.2 Chile

Following the virtual workshop on June 22, a Google Form response was received from Chile (Table 6). The consultation meeting with Chile took place on July 11, 2022 (22:00~24:00, KST). The meeting was attended by Dr. Jongmyoung Lee and other researchers of OSEAN as consultants and Ms. Macarena Maldifassi Gatica and Ms. Claudia Valenzuela Cuevas of the General Directorate of Maritime Territory and Merchant Marine as respondents attended on behalf of Chile. Table 6 shows selections of Chile, generating recommended monitoring programs or methodologies. Below is a summary of finding the optimal monitoring methodology by following questions and answers, and discussions in the meeting.

Table 6. Google Form result from Chile

Criteria	Selections of Chile
1. **Goals and Objectives**: What are the objectives of your monitoring program? (You may select multiple answers if necessary)	Identifying status or level of pollution (Chile LS, China MDMP, Korea RA)
	Identifying changes over time in the amount, composition, type, and source (EU MSFD TGML, Korea NBLMP, NOAA MDMAP)
	Raising public awareness and building capacity (ICC, New Zealand LI)
2. **Size:** What target size will you be monitoring?	Debris larger than 25 mm (China NCCMP, EU MARLIN, EU MLW, EU MSFD TGML, Indonesia MDMG, Japan DBDM, Korea NBLMP, NOAA MDMAP)
	All visible debris (ICC, Clean Swell)
3. **Category**: Will you be surveying all types of marine debris or only specific target items? If you plan on surveying all of the debris, will you be categorizing by material or by source?	All item survey - material categorization (EU MARLIN, EU MSFD TGML, EU MLW, EU OSPAR MML, Indonesia MDMG, Japan DBDM, Korea NBLMP, NOAA MDMAP)
	All item survey - Usage categorization (ICC ~2012)
4. **Spatial Scale**: Will you be monitoring shoreline debris locally or nationally? What is your geographical scope?	Domestic monitoring (British BCP, Chile LS, China MDMP, Indonesia MDMG, Japan DBDM, Korea NBLMP, Viet Nam MAPPL)
	Regional monitoring (Australia MDI, EU MARLIN, EU MSFD TGML, EU MLW, EU OSPAR MML, MED DeFishGear, New Zealand LI)
5. **Site Selection**: What standards will you use when selecting a monitoring location? Do you plan on selecting a site based on a structured methodology?	Spatial site selection (Chile LS, China MDMP, Japan DBDM, EU MARLIN, EU MSFD TGML, EU OSPAR MML)
6. **Training**: How will you recruit and train surveyors? Do surveyors need training prior to conducting surveys?	Survey manual or simple online training program (EU OSPAR MML, Indonesia SBDP, New Zealand LI, NOAA MDMAP),
	Face-to-face or on-site training program (China MDMP, EU MARLIN, GPLBP, Japan DBDM, Korea NBLMP, Viet Nam MAPPL)
7. **Interval**: How often will you be monitoring? Are you looking to	Biannual (GPLBP, Viet Nam MAPPL)

understand the seasonal impact on marine debris?	
8. **Measurement**: What will you be measuring when monitoring? Do you plan on collecting and measuring debris?	Collect and measure the number of debris only (Clean Swell, EU MARLIN, EU MLW, EU MSFD TGML, EU OSPAR MML, NOAA MDMAP)
	Collect and measure the number of debris and its weight (China MDMP, Indonesia MDMG, Korea NBLMP, MED DeFishGear, Viet Nam MAPPL)
9. **Quality management**: How will you be managing the quality of your data?	On-site: Providing manual (Australia MDI, Clean Swell, ICC, Litterati, MDT, NOAA MDMAP)
	On-site: Providing manual and training (China MDMP, EU MARLIN, Japan DBDM, Korea NBLMP, Viet Nam MAPPL)
10. **Database**: Where will you be submitting your monitoring data? Do you plan on creating a separate database for your monitoring program?	Customized DB (Chile LS, China MDMP, EU MARLIN, GPLBP, Korea NBLMP)
	DB requiring the approval of the administrator (EU MLW, EU MSFD TGML, New Zealand LI)
11. **Data Analysis**: How will you be analyzing your monitoring data? What analysis is needed to achieve your goals and objectives?	In-house specialist (Chile LS, EU MARLIN, EU OSPAR MML, Indonesia SBDP, Japan DBDM, Korea NBLMP, MED DeFishGear, NOAA MDMAP, Viet Nam MAPPL)

[Status of marine debris monitoring] Is there an ongoing or planned marine debris monitoring program in Chile?

There are technically two marine debris monitoring efforts that are being carried out in Chile. First, since 2008, Chile has participated in the International Coastal Cleanup (ICC). This has helped collect a lot of data over the years, but there were limitations as ICC is only conducted once a year and the number of participants, data collection, and cleanup was significantly reduced in 2020 due to COVID-19 which was an external factor affecting the survey.

Second, in 2018, after taking a course led by Dr. Martin Thiel, a monitoring protocol requiring a five-day survey based on GESAMP guidelines was created. By the end of 2018, 13 beaches were monitored on two occasions. Starting in 2019, this monitoring effort was expected to be conducted biannually (in autumn and spring), but during this time civil unrest made it extremely difficult to conduct any monitoring activities. In 2020, ICC and the five-day monitoring effort were canceled because of COVID-19 pandemic.

The Ministry of Environment and the Maritime Authority are interested in harmonizing the methodologies so that the results will be easily comparable. A simplified monitoring program, including macro and micro plastic debris, for a wide area of coastlines at a low cost is needed for Chile. The study and interest on microplastics in crustaceans, rivers, lakes, and estuaries in Chile are increasing. Expertise to be required for economywide monitoring will be increasing.

[Confirming the results of Google Form questionnaire] What is the most appropriate monitoring methodology for Chile?

In the course of reviewing Chile’s Google Form in the consulting meeting, Chile's requirements and conditions for marine debris monitoring became clear. Initially, Chile wanted to survey all visible debris, but it was agreed that only monitoring debris larger than 25 mm (macro debris) would be feasible. To meet Chile’s goal in conducting economywide monitoring, a simple monitoring method was favored and therefore a material-based classification of debris was decided. Chile wanted to conduct seasonal surveys on 13 to 15 coastal sites along its coastline, but upon discussion, it was decided that biannual surveys would suffice as officials didn't have the time to do frequent surveys.

In Chile, budget cuts seem to affect overall monitoring design. A low-cost way to do this is to 1) conduct online training for people in remote areas to participate, 2) combine inorganic chemical monitoring with marine debris monitoring and doing it all at once, and 3) use the existing DB with the approval process from DB administrator.

Based on the results of these discussions, it was decided that the monitoring program that Chile should first refer to was the NOAA MDMAP. NOAA MDMAP uses a method to measure the number of debris larger than 25 mm by material. Participation is available to those from all over the world and resources are available on the website to guide surveyors on monitoring marine debris. In addition, there is a web DB with easy accessibility which allows anyone to register or inquire the results of the survey by simply going through a registration process.

[Introduction to the most appropriate monitoring methodology and advising on initiatives] How to develop marine debris monitoring program in Chile?

The consultants used NOAA MDMAP's website and guidance materials to learn about the program and its methodology. NOAA’s monitoring toolbox provides the necessary resources for participants to select the beaches to be surveyed and to conduct the field survey. Participants can select the beaches to be surveyed on their own, which must be at least 100 meters long and directly accessible without being interrupted by headland or waterway. What is unique about the NOAA MDMAP is that it randomly selects four 5 m transects from a 100 m beach and records the debris within that designated area. By examining the debris only within a narrow section, the accuracy of the survey can be improved and statistical representativeness can be increased by obtaining several survey results from one beach. The surveyor records the number of all types of debris larger than 25 mm on the beach surface from the water edge of the selected transect to the back barrier (including 2 m in).

Post-survey debris removal is optional but recommended. In addition to the given debris category, surveyors can add and record the debris of interest as a ‘custom item.’ NOAA MDMAP provides three guidelines for data quality management: 1) familiarizing surveyors with the monitoring guidelines; 2) conducting consistency tests that independently classify debris and compare the results at least once a year, and 3) ensuring that newly joined surveyors are guided by an experienced surveyor.

[Discussing the resolution of monitoring challenges] What are the challenges for developing and implementing a marine debris monitoring program in Chile?

The biggest challenge facing marine debris monitoring in Chile is the lack of time. It was very difficult to convene officials to conduct a five-day survey in many areas, the second effort of monitoring. Through the consultation meeting, Chilean monitoring officers found that NOAA MDMAP can be used by anyone from any economy, not just the United States, and that the survey method is relatively simple.

[Finalizing consultation] What will be the most appropriate methodology for Chile?

Cost and time limitation seem to be key criteria in Chile. The Chilean member economy was advised to choose NOAA MDMAP and it would be necessary to have internal discussions to promote monitoring efforts using NOAA MDMAP in Chile. The OSEAN consultants can introduce and guide MDMAP to Chilean officials upon request from Chile.

5 RECOMMENDATION

This project reviewed and summarized a total of 31 monitoring programs and methodologies. Of the 21 economies in the APEC region, nine member economies already have their own monitoring methodologies based on their respective goals and objectives (Table 2). There isn’t a particular monitoring methodology to adamantly suggest for member economies that have yet to start any monitoring, but this document will provide guidance to help find methodologies that will complement existing monitoring programs or the needs of member economies.

Determining a monitoring methodology is a process of compromise that requires aligning objectives or goals to a set of criteria. This document suggests five elements and 11 decision criteria (Table 4). We recommend examining the entire decision-making framework before selecting interested criteria or conditions that will present limitations when conducting monitoring efforts. When looking for examples that suit the needs and conditions of each member economy, available options will be narrowed down. Although 'cost' (including budget and manpower) is not presented as a separate criterion, it should always be considered when selecting a monitoring methodology or program. For member economies with limited manpower or resources, Table 7 is recommended, which summarizes the first recommendations for each criterion. Some parts are based on the authors' long-term monitoring experiences and subjective judgment. As there has currently been no consensus methodology, it is presented here even if there is a lack of scientific recommendation basis. Following the recommendations in Table 7, when choosing an existing monitoring program in practice, it can still be difficult to decide. This is because many programs appear duplicated or different cases are selected for each criterion. So, Figure 16 presents an example with a narrower selection. We hope that it will be helpful for users' convenience and understanding.

Table 7. Recommendation to the APEC economies to design a domestic monitoring program. The elements and criteria are explained in Table 4 in detail.

Elements of Monitoring	Decision Criteria	Recommendation
Goals / Objectives	Objective	Clearly define own goals and objectives and select one or more objectives below. 1) Identifying baseline, state, or level of pollution 2) Identifying changes over time in the amount, composition, type and source 3) Conducting a spatial assessment of marine debris 4) Providing basic information to developing countermeasures 5) Raising public awareness and building capacity
Debris Target	Size	· Mainly focus on macro size debris (> 25 mm). Do not change the size range during the total monitoring period. As the size becomes smaller, the cost to be invested increases exponentially.
	Category	· Classify materials of debris and subclassify specific items under the material category; or classify usages of debris and subclassify specific items under the usage category · Mainly focus on plastic material; or focus on packaging or fishing-related items · If resources are limited, select items of special interest or items commonly found on most beaches as indicators.
Scale	Spatial Scale	· Start small at first and expand the geographic scale after conducting a pilot survey.
	Site Selection	· Start with a small number of sites, collect the data, and then increase the sites adjusted to be representative and repetitive with given human resources and cost. · Make stratified selections to reflect geographic, environmental, social, and industrial characteristics to achieve 'Objective 3' if necessary.
Data Collection	Training	· Search the manual first. A survey method and data entry form will be presented. If you want to obtain detailed data and scientifically meaningful results, a separate training course is required.

	Interval	· Acquire baseline data by conducting one survey first. Then you will achieve 'Objective 1'. After that, allocate the survey interval in consideration of the number of people and the budget required for the survey. Conduct surveys at least twice a year reflecting the characteristics of the season to achieve 'Objective 2' if necessary.
	Measurement	· Count number of debris per length of shoreline (e.g. number of debris per m) as a basic measurement. Additionally weight categorized debris per length (e.g. gram of plastic debris per meter). · Number per area of shoreline (e.g. 100 m^2) is a recommended indicator by UNEP (2021). · Collect all debris along the 100 m of shoreline or from transects. Clean the survey area after measurement · For quick and wide surveys, count the numbers or take pictures without collecting and cleaning
Management	**Quality Management**	· On-site training, joint survey by trainers and trainees, and data verification are necessary to achieve 'Objective 4', which requires a lot of effort and resources.
	Database	· Search a web-based DB which requires the approval of an administrator before registering the data and can be customized to achieve 'Objectives 1 to 4' for higher quality. · Use completely open web-based DB for 'Objective 5'.
	Data Analysis	· Search a web-based DB to obtain descriptive statistics (the amount and proportion of marine debris by region and time or the most abundant items in number). · Expert help is essential for professional analysis, such as evaluating temporal trends and analyzing drivers affecting marine debris generation. Seek 'Official Development Assistance' project opportunities or funding in countries with advanced monitoring experience.

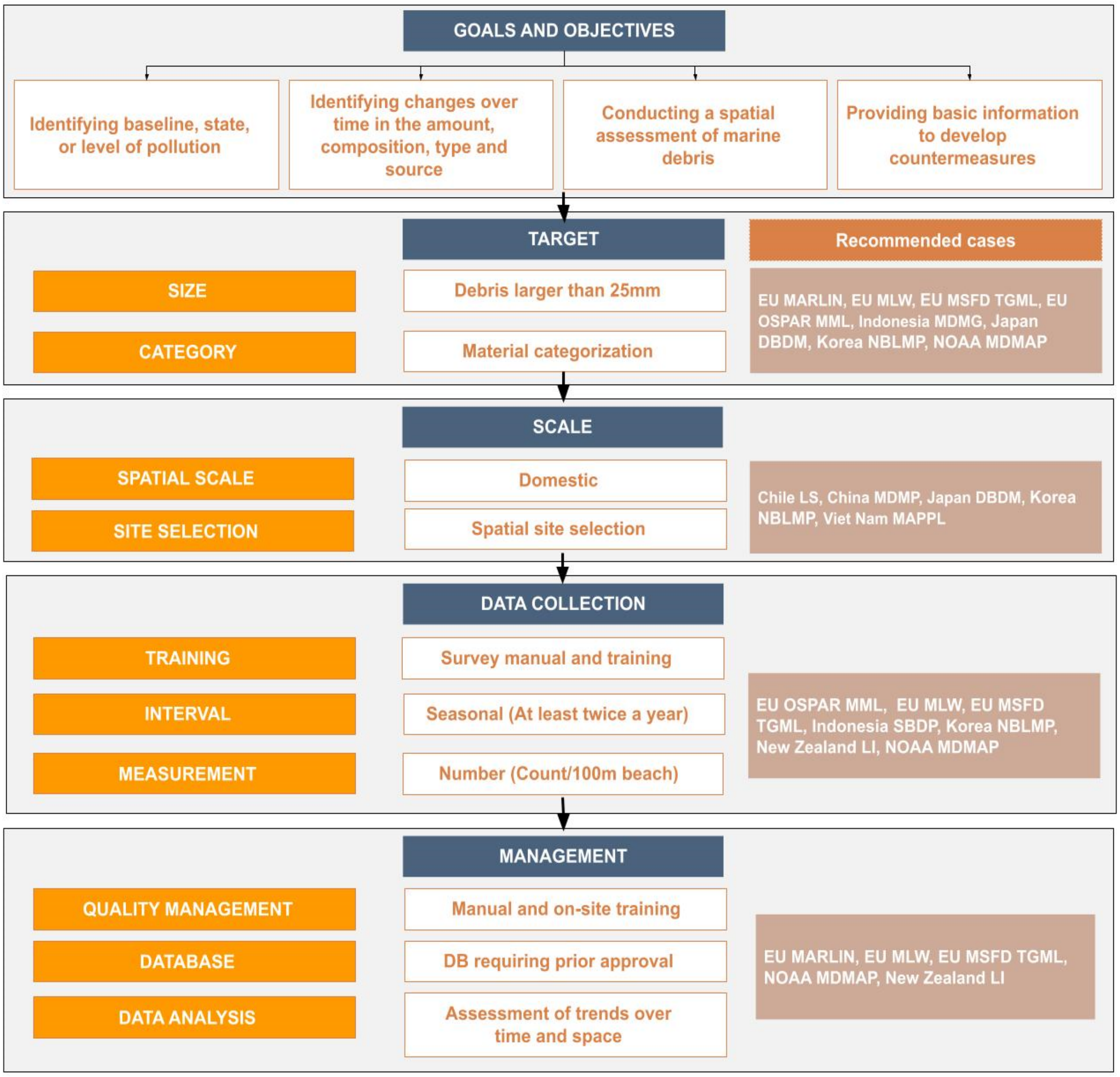

Figure 16. A decision framework of an example with a narrower selection following Table 7.

6 REFERENCES

Addamo, A., Laroche, P., Hanke, G., 2018. Top Marine Beach Litter Items in Europe [WWW Document]. JRC Publications Repository. https://doi.org/10.2760/496717.

Alkalay, R., Pasternak, G., Zask, A., 2007. Clean-coast index–A new approach for beach cleanliness assessment. Ocean & Coastal Management, 50, 352–362.

Al Nahian, S., Rakib, Md.R.J., Haider, S.M.B., Kumar, R., Walker, T.R., Khandaker, M.U., Idris, A.M., 2022. Baseline marine litter abundance and distribution on Saint Martin Island, Bay of Bengal, Bangladesh. Marine Pollution Bulletin 183, 114091. https://doi.org/10.1016/j.marpolbul.2022.114091.

Andriolo, U., Gonçalves, G., Rangel-Buitrago, N., Paterni, M., Bessa, F., Gonçalves, L.M.S., Sobral, P., Bini, M., Duarte, D., Fontán-Bouzas, Á., Gonçalves, D., Kataoka, T., Luppichini, M., Pinto, L., Topouzelis, K., Vélez-Mendoza, A., Merlino, S., 2021. Drones for litter mapping: An inter-operator concordance test in marking beached items on aerial images. Marine Pollution Bulletin 169, 112542. https://doi.org/10.1016/j.marpolbul.2021.112542.

Asensio-Montesinos, F., Anfuso, G., Aguilar-Torrelo, M.T., Oliva Ramírez, M., 2021. Abundance and Temporal Distribution of Beach Litter on the Coast of Ceuta (North Africa, Gibraltar Strait). Water 13, 2739. https://doi.org/10.3390/w13192739.

Bai, M., Zhu, L., An, L., Peng, G., Li, D., 2018. Estimation and prediction of plastic waste annual input into the sea from China. Acta Oceanol. Sin. 37, 26–39. https://doi.org/10.1007/s13131-018-1279-0.

Barboza, L.G.A., Dick Vethaak, A., Lavorante, B.R.B.O., Lundebye, A.-K., Guilhermino, L., 2018. Marine microplastic debris: An emerging issue for food security, food safety and human health. Marine Pollution Bulletin 133, 336–348. https://doi.org/10.1016/j.marpolbul.2018.05.047.

Barnardo, T., Ribbink, A., 2020. African Marine Litter Monitoring Manual. (Report). African Marine Waste Network, Sustainable Seas Trust. https://doi.org/10.25607/OBP-923.

Boerger, C.M., Lattin, G.L., Moore, S.L., Moore, C.J., 2010. Plastic ingestion by planktivorous fishes in the North Pacific Central Gyre. Marine Pollution Bulletin 60, 2275–2278. https://doi.org/10.1016/j.marpolbul.2010.08.007.

Bouzekry, A., Mghili, B., Aksissou, M., 2022. Addressing the challenge of marine plastic litter in the Moroccan Mediterranean: A citizen science project with schoolchildren. Marine Pollution Bulletin 184, 114167. https://doi.org/10.1016/j.marpolbul.2022.114167.

Brennan, E., Wilcox, C., Hardesty, B.D., 2018. Connecting flux, deposition and resuspension in coastal debris surveys. Science of the Total Environment 644, 1019–1026. https://doi.org/10.1016/j.scitotenv.2018.06.352.

Browne, M.A., Chapman, M.G., Thompson, R.C., Amaral Zettler, L.A., Jambeck, J., Mallos, N.J., 2015. Spatial and Temporal Patterns of Stranded Intertidal Marine Debris: Is There a Picture of Global Change? Environmental Science and Technology, 49, 7082–7094. https://doi.org/10.1021/es5060572.

Burgess, H. K., Herring, C. E., Lippiatt, S., Lowe, S., & Uhrin, A. V., 2021. NOAA Marine Debris Monitoring and Assessment Project Shoreline Survey Guide. National Oceanic and Atmospheric Administration Marine Debris Program.

Chen, H., Wang, S., Guo, H., Lin, H., Zhang, Y., 2020. A nationwide assessment of litter on China's beaches using citizen science data. Environmental Pollution 258, 113756. https://doi.org/10.1016/j.envpol.2019.113756.

Cheshire, A., Adler, E., Barbière, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R. T., Kinsey, S., Kusui, E. T., others, 2009. UNEP/IOC guidelines on survey and monitoring of marine litter. United Nations Environment Programme, Regional Seas Programme.

Clark, G. F., Gacutan, J., Lawther, R., Johnston, E. L., Tait, H., Bednarz, T., 2021. A visualization tool for citizen-science marine debris big data. Water International, 46(2), 211–223. https://doi.org/10.1080/02508060.2021.1888495.

Coordinating Body on the Seas of East Asia & Commonwealth Scientific and Industrial Research Organisation, 2022. Regional Guidance on Harmonized National Marine Litter Monitoring Programmes. Monitoring Efforts and Recommendations for National Marine Litter Monitoring Programmes. Bangkok: United Nations Environment Programme.

Cordova, R., 2018. Standard operating procedure monitoring. Pusat Penelitian Oseanografi LIPI.

Deidun, A., Gauci, A., Lagorio, S., Galgani, F., 2018. Optimising beached litter monitoring protocols through aerial imagery. Marine Pollution Bulletin 131, 212–217. https://doi.org/10.1016/j.marpolbul.2018.04.033.

Eriksson, C., Burton, H., Fitch, S., Schulz, M., van den Hoff, J., 2013. Daily accumulation rates of marine debris on sub-Antarctic island beaches. Marine Pollution Bulletin, 66, 199–208. https://doi.org/10.1016/j.marpolbul.2012.08.026.

Escobar-Sánchez, G., Haseler, M., Oppelt, N., Schernewski, G., 2021. Efficiency of Aerial Drones for Macrolitter Monitoring on Baltic Sea Beaches. Frontiers in Environmental Science 8.

Fallati, L., Polidori, A., Salvatore, C., Saponari, L., Savini, A., Galli, P., 2019. Anthropogenic Marine Debris assessment with Unmanned Aerial Vehicle imagery and deep learning: A case study along the beaches of the Republic of Maldives. Science of The Total Environment 693, 133581. https://doi.org/10.1016/j.scitotenv.2019.133581.

Fujieda, S., Kojima, A., Kanehiro, H., 2006. Monitoring Marine Debris Using Disposable Lighters as an Indicator. Journal of the Japan Society of Waste Management Expert17(2), 117–124. https://doi.org/10.3985/jswme.17.117.

Galgani, F., Hanke, G., Werner, S., L, O., Nilsson, P., Fleet, D., Kinsey, S., RC, T., Van Franeker, J., Vlachogianni, T., Scoullos, M., Mira Veiga, J., Palatinus, A., Matiddi, M., Maes, T., Korpinen, S., A, B., H, L., Gago, J., Liebezeit, G., 2013. Guidance on Monitoring of Marine Litter in European Seas.

GESAMP, 2019. Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean (Kershaw P. J., Turra A. and Galgani F. editors), (IMO/FAO/UNESCO-IOC/UNIDO/WMO/IAEA/UN/UNEP/UNDP/ISA Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. https://research.wur.nl/en/publications/guidelines-for-the-monitoring-and-assessment-of-plastic-litter-in.

Hanke, G., F. Galgani, S. Werner, L. Oosterbaan, P. Nilsson, D. Fleet, S. Kinsey, R. Thompson, J. A. Van Franeker, T. Vlachogianni, A. Palatinus, M. Scoullos, J.M. Veiga, M. Matiddi, L. Alcaro, T. Maes, S. Korpinen, A. Budziak, H. Leslie, J. Gago, G. Liebezeit, 2013. Guidance on monitoring of marine litter in European seas. European Commission, 124 pp.

Hanke G., Walvoort D., van Loon W., Addamo A.M., Brosich A., del Mar Chaves Montero M., Molina Jack M.E., Vinci M., Giorgetti A., EU Marine Beach Litter Baselines, EUR 30022 EN, Publications Office of the European Union, Luxemburg, 2019, ISBN 978-92- 76-14243-0, doi:10.2760/16903, JRC114129.

Hardesty, Britta Denise, Chris Wilcox, Qamar Schuyler, TJ Lawson and Kimberley Opie., 2017. Developing a baseline estimate of amounts, types, sources and distribution of coastal litter – an analysis of US marine debris data. Version 1.2. CSIRO: EP167399

Harris, L., Liboiron, M., Charron, L., Mather, C., 2021. Using citizen science to evaluate extended producer responsibility policy to reduce marine plastic debris shows no reduction in pollution levels. Marine Policy, 123, 104319. https://doi.org/10.1016/j.marpol.2020.104319.

HELCOM, 2018. Overview of available methods to monitor marine plastic litter (pp 1-47).

Hidalgo-Ruz, V., Honorato-Zimmer, D., Gatta-Rosemary, M., Nuñez, P., Hinojosa, I. A., Thiel, M., 2018. Spatio-temporal variation of anthropogenic marine debris on Chilean beaches. Marine Pollution Bulletin, 126, 516–524. https://doi.org/10.1016/j.marpolbul.2017.11.014.

Hidalgo-Ruz, V., Thiel, M., 2015. The contribution of citizen scientists to the monitoring of marine litter. In Marine Anthropogenic Litter (pp 429–447). Springer. http://link.springer.com/chapter/10.1007/978-3-319-16510-3_16.

Hong, S., Lee, J., Jang, Y.C., Kim, Y.J., Kim, H.J., Han, D., Hong, S.H., Kang, D., Shim, W.J., 2013. Impacts of marine debris on wild animals in the coastal area of Korea. Marine Pollution Bulletin 66, 117–124. https://doi.org/10.1016/j.marpolbul.2012.10.022

Hong, S., Lee, J., Kang, D., Choi, H.-W., Ko, S.-H., 2014. Quantities, composition, and sources of beach debris in Korea from the results of nationwide monitoring. Marine Pollution Bulletin, 84(1–2), 27–34. https://doi.org/10.1016/j.marpolbul.2014.05.051.

Hong, S., Lee, J., Lim, S., 2017. Navigational threats by derelict fishing gear to navy ships in the Korean seas. Marine Pollution Bulletin 119. https://doi.org/10.1016/j.marpolbul.2017.04.006.

Hong, S., Lee, J., Lee, J., 2018. Quantities of marine debris along the coastline in South Korea have significantly decreased. Sixth International Marine Debris Conference.

IUCN Viet Nam, Greenhub, 2021. Monitoring and Assessment programme on plastic litter in Viet Nam shoreline – Report 2019 (p 13).

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Narayan, R., Law, K.L., 2015. Plastic waste inputs from land into the ocean. Science 347, 768–771. https://doi.org/10.1126/science.1260352.

Jang, Y.C., Hong, S., Lee, J., Lee, M.J., Shim, W.J., 2014. Estimation of lost tourism revenue in Geoje Island from the 2011 marine debris pollution event in South Korea. Marine Pollution Bulletin, 81, 49–54. https://doi.org/10.1016/j.marpolbul.2014.02.021.

Kako, S., Isobe, A., Magome, S., 2012. Low altitude remote-sensing method to monitor marine and beach litter of various colors using a balloon equipped with a digital camera. Marine Pollution Bulletin, 64, 1156–1162. https://doi.org/10.1016/j.marpolbul.2012.03.024.

Kako, S., Morita, S., Taneda, T., 2020. Estimation of plastic marine debris volumes on beaches using unmanned aerial vehicles and image processing based on deep learning. Marine Pollution Bulletin, 155, 111127. https://doi.org/10.1016/j.marpolbul.2020.111127.

Kataoka, T., Hinata, H., Kako, S., 2012. A new technique for detecting colored macro plastic debris on beaches using webcam images and CIELUV. Marine Pollution Bulletin, 64, 1829–1836. https://doi.org/10.1016/j.marpolbul.2012.06.006.

Lebreton, L.C.M., van der Zwet, J., Damsteeg, J.-W., Slat, B., Andrady, A., Reisser, J., 2017. River plastic emissions to the world's oceans. Nat Commun 8, 15611. https://doi.org/10.1038/ncomms15611.

Lebreton, L., Royer, S.-J., Peytavin, A., Strietman, W.J., Smeding-Zuurendonk, I., Egger, M., 2022. Industrialised fishing nations largely contribute to floating plastic pollution in the North Pacific subtropical gyre. Sci Rep 12, 12666. https://doi.org/10.1038/s41598-022-16529-0.

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., Hajbane, S., Cunsolo, S., Schwarz, A., Levivier, A., Noble, K., Debeljak, P., Maral, H., Schoeneich-Argent, R., Brambini, R., Reisser, J., 2018. Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. Sci Rep 8, 4666. https://doi.org/10.1038/s41598-018-22939-w.

Lee, H.-J., Song, N.-S., Kim, J.-S., Kim, S.-K., 2021. Variation and Uncertainty of Microplastics in Commercial Table Salts: Critical Review and Validation. Journal of Hazardous Materials, 402, 123743. https://doi.org/10.1016/j.jhazmat.2020.123743.

Lee, J., Hong, S., Lee, J., 2019. Rapid assessment of marine debris in coastal areas using a visual scoring indicator. Marine Pollution Bulletin, 149, 110552. https://doi.org/10.1016/j.marpolbul.2019.110552.

Lippiatt, S., Opfer, S., Arthur, C., 2013. Marine debris monitoring and assessment: Recommendations for monitoring debris trends in the marine environment.

Meijer, L., van Emmerik, T., Lebreton, L., Schmidt, C., Ent, R., 2019. Over 1000 rivers accountable for 80% of global riverine plastic emissions into the ocean. https://doi.org/10.31223/osf.io/zjgty.

Martin, C., Parkes, S., Zhang, Q., Zhang, X., McCabe, M.F., Duarte, C.M., 2018. Use of unmanned aerial vehicles for efficient beach litter monitoring. Marine Pollution Bulletin, 131, 662–673. https://doi.org/10.1016/j.marpolbul.2018.04.045.

McIlgorm, A., Raubenheimer, K., McIlgorm, D.E., Nichols, R., 2022. The cost of marine litter damage to the global marine economy: Insights from the Asia-Pacific into prevention and the cost of inaction. Marine Pollution Bulletin, 174, 113167. https://doi.org/10.1016/j.marpolbul.2021.113167.

Miliute-Plepiene, J., Fråne, A., Haikonen, K., Youhanan, L., 2018. Overview of available methods to monitor marine plastic litter Incl. Method for riverine litter monitoring developed within BLASTIC. [Report]. IVL Swedish Environmental Research Institute. https://doi.org/10.25607/OBP-763.

Ministry of Environment, Japan, 2019. Report on Comprehensive Examination of Measures Against Drifting Debris (Japanese).

Ministry of Oceans and Fisheries & Korea Marine Environment Management Corporation, 2019. Guide to Korea National Beach Litter Monitoring Program.

Nelms, S.E., Duncan, E.M., Broderick, A.C., Galloway, T.S., Godfrey, M.H., Hamann, M., Lindeque, P.K., Godley, B.J., 2016. Plastic and marine turtles: a review and call for research. ICES Journal of Marine Science, 73, 165–181. https://doi.org/10.1093/icesjms/fsv165.

Nelms, S. E., Eyles, L., Godley, B. J., Richardson, P. B., Selley, H., Solandt, J.-L., Witt, M. J., 2020. Investigating the distribution and regional occurrence of anthropogenic litter in English marine protected areas using 25 years of citizen-science beach clean data. Environmental Pollution, 263, 114365. https://doi.org/10.1016/j.envpol.2020.114365

NOWPAP, 2007. Guidelines for Monitoring Marine Litter on the Beaches and Shorelines of the Northwest Pacific Region. https://www.unep.org/nowpap/resources/toolkits-manuals-and-guides/guidelines-monitoring-marine-litter-beaches-and-shorelines.

Olivelli, A., Hardesty, B.D., Wilcox, C., 2020. Coastal margins and backshores represent a major sink for marine debris: insights from a continental-scale analysis. Environ. Res. Lett. 15, 074037. https://doi.org/10.1088/1748-9326/ab7836.

OSPAR Commission, 2007. OSPAR Pilot Project on Monitoring Marine Beach Litter: Monitoring of Marine Litter on Beaches in the OSPAR Region. OSPAR Commission, London.

OSPAR Commission, 2010. Guideline for monitoring marine litter on the beaches in the OSPAR maritime area. OSPAR Commission: London, UK, 1.

OSPAR Commission, 2017. CEMP Guidelines for monitoring marine litter washed ashore and/or deposited on coastlines (beach litter) (OSPAR agreement 2017-05).

Register, K., 2021. Deadly Litter: Balloons & Plastic Ribbons on Virginia's Coastal Beaches. Clean Virginia Waterways, Longwood University. Farmville, VA.

Republic of Indonesia, 2020. Marine Debris Monitoring Guideline.

Ribic, C. A., Sheavly, S. B., Rugg, D. J., Erdmann, E. S., 2010. Trends and drivers of marine debris on the Atlantic coast of the United States 1997–2007. Marine Pollution Bulletin, 60(8), 1231–1242.

Richardson, K., Hardesty, B.D., Wilcox, C., 2019. Estimates of fishing gear loss rates at a global scale: A literature review and meta-analysis. Fish and Fisheries 20, 1218–1231. https://doi.org/10.1111/faf.12407.

Roman, L., Hardesty, B.D., Leonard, G.H., Pragnell-Raasch, H., Mallos, N., Campbell, I., Wilcox, C., 2020. A global assessment of the relationship between anthropogenic debris on land and the seafloor. Environmental Pollution 264, 114663. https://doi.org/10.1016/j.envpol.2020.114663.

Ryan, P.G., Dilley, B.J., Ronconi, R.A., Connan, M., 2019. Rapid increase in Asian bottles in the South Atlantic Ocean indicates major debris inputs from ships. Proceedings of the National Academy of Sciences 116, 20892–20897. https://doi.org/10.1073/pnas.1909816116.

Ryan, P., Moore, C., Van Franeker, J., Moloney, C., 2009. Monitoring the abundance of plastic debris in the marine environment. Philosophical transactions of the Royal Society of London. Series B, Biological sciences 364, 1999–2012. https://doi.org/10.1098/rstb.2008.0207.

Ryan, P.G., Weideman, E.A., Perold, V., Moloney, C.L., 2020. Toward Balancing the Budget: Surface Macro-Plastics Dominate the Mass of Particulate Pollution Stranded on Beaches. Frontiers in Marine Science 7.

Santodomingo, N., Perry, C., Waheed, Z., Syed Hussein, M.A. bin, Rosedy, A., Johnson, K.G., 2021. Marine litter pollution on coral reefs of Darvel Bay (East Sabah, Malaysia). Marine Pollution Bulletin 173, 112998. https://doi.org/10.1016/j.marpolbul.2021.112998.

Schuyler, Q., Hardesty, B. D., Lawson, T., Opie, K., Wilcox, C., 2018a. Economic incentives reduce plastic inputs to the ocean. Marine Policy, 96, 250-255. https://doi.org/10.1016/j.marpol.2018.02.009.

Schuyler, Q., Willis, K., Lawson, T. J., Mann, V., Wilcox, C., 2018b. Handbook of survey methodology: Plastics leakage. Hobart, Australia: CSIRO. ePublish EP178700.

Serra-Gonçalves, C., Lavers, J. L., Bond, A. L., 2019. Global review of beach debris monitoring and future recommendations. Environmental Science & Technology, 53(21), 12158–12167.

Sheavly, S. B., 2007. National Marine Debris Monitoring Program: Final Program Report, Data Analysis and Summary.

Sibaja-Cordero, J.A., Gómez-Ramírez, E.H., 2022. Marine litter on sandy beaches with different human uses and waste management along the Gulf of Nicoya, Costa Rica. Marine Pollution Bulletin 175, 113392. https://doi.org/10.1016/j.marpolbul.2022.113392.

Simeonova, A., Chuturkova, R., 2020. Macroplastic distribution (Single-use plastics and some Fishing gear) from the northern to the southern Bulgarian Black Sea coast. Regional Studies in Marine Science, 37, 101329. https://doi.org/10.1016/j.rsma.2020.101329.

Smail, E., Campbell, J., Takaki, D., Plag, H.-P., Garello, R., Djavidnia, S., Moutinho, J., El Serafy, G., Giorgetti, A., Vinci, M., 2020. A Global Platform for Monitoring Marine Litter and Informing Action. Unpublished. https://geoblueplanet. org/wp-content/uploads/2020/03/Marine-Litter-White-Paper-Draft_07Mar2020. pdf.

Smith, S.D.A., Markic, A., 2013. Estimates of Marine Debris Accumulation on Beaches Are Strongly Affected by the Temporal Scale of Sampling. PLOS ONE 8, e83694. https://doi.org/10.1371/journal.pone.0083694.

Smith, L., Turrell, W.R., 2021. Monitoring Plastic Beach Litter by Number or by Weight: The Implications of Fragmentation. Frontiers in Marine Science 8.

Takaya, K., Shibata, A., Mizuno, Y., Ise, T., 2022. Unmanned aerial vehicles and deep learning for assessment of anthropogenic marine debris on beaches on an island in a semi-enclosed sea in Japan. Environ. Res. Commun. 4, 015003. https://doi.org/10.1088/2515-7620/ac473b.

Thiel, M., Hong, S., Jambeck, J. R., Gatta-Rosemary, M., Honorato-Zimmer, D., Kiessling, T., Knickmeier, K., Kruse, K., 2017. Marine litter – bringing together citizen scientists from around the world. In Citizen Science for Coastal and Marine Conservation. Routledge.

Thiel, M., Luna-Jorquera, G., Álvarez-Varas, R., Gallardo, C., Hinojosa, I.A., Luna, N., Miranda-Urbina, D., Morales, N., Ory, N., Pacheco, A.S., Portflitt-Toro, M., Zavalaga, C., 2018. Impacts of Marine Plastic Pollution From Continental Coasts to Subtropical Gyres—Fish, Seabirds, and Other Vertebrates in the SE Pacific. Frontiers in Marine Science 5.

Trapani, C., O'Hara, K., Register K., 2018. Balloon Litter on Virginia's Remote Beaches: Results of Monitoring from 2013 through 2017. Clean Virginia Waterways, Longwood University.

Turner, A., Amos, S.L., Williams, T., 2021. Coastal dunes as a sink and secondary source of marine plastics: A study at Perran Beach, southwest England. Marine Pollution Bulletin 173, 113133. https://doi.org/10.1016/j.marpolbul.2021.113133.

Uhrin, A. V., Lippiatt, S., Herring, C. E., Dettloff, K., Bimrose, K., Butler-Minor, C., 2020. Temporal Trends and Potential Drivers of Stranded Marine Debris on Beaches Within Two US National Marine Sanctuaries Using Citizen Science Data. Frontiers in Environmental Science. https://doi.org/10.3389/fenvs.2020.604927.

Uhrin, A.V., Hong, S., Burgess, H.K., Lim, S., Dettloff, K., 2022. Towards a North Pacific long-term monitoring program for ocean plastic pollution: A systematic review and recommendations for shorelines. Environmental Pollution 310, 119862. https://doi.org/10.1016/j.envpol.2022.119862.

UNEP, 2005. Marine litter, an analytical overview. 50 pp.

UNEP, 2020. Third Regional Overview of marine litter in the NOWPAP region, United Nations Environment Programme, Nairobi, Kenya. https://wedocs.unep.org/handle/20.500.11822/ 35893;jsessionid=2BB67F1E42338799EAC6CAEF44A7F718.

UNEP, 2021. Understanding the State of the Ocean: A Global Manual on Measuring SDG 14.1.1, SDG 14.2.1 and SDG 14.5.1. Nairobi.

Van der Velde, T.D., Milton, D., Wilcox, C., Lawson, T.J., Lansdell, M., Davis, G., Perkins, G., Hardesty, B.D. 2017. Comparison of marine debris data collected by researchers and citizen scientists: Is citizen science data worth the effort? Biological Conservation 208: 127-138.

Van Loon, W., Hanke, G., Fleet, D., Werner, S., Barry, J., Strand, J., Eriksson, J., Galgani, F., Gräwe, D., Schulz, M., Vlachogianni, T., Press, M., Blidberg, E., Walvoort, D., 2020. A European Threshold Value and Assessment Method for Macro Litter on Coastlines. (Report). Publications Office of the European Union. https://doi.org/10.2760/54369.

Vlachogianni, T. (2017). Methodology for Monitoring Marine Litter on Beaches: Macro-Debris (> 2.5 cm).

Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, C., Mazziotti, C., Tutman, P., Varezić, D.B., Palatinus, A., Trdan, Š., Peterlin, M., Mandić, M., Markovic, O., Prvan, M., Kaberi, H., Prevenios, M., Kolitari, J., Kroqi, G., Fusco, M., Kalampokis, E., Scoullos, M., 2018. Marine litter on the beaches of the Adriatic and Ionian Seas: An assessment of their abundance, composition and sources. Marine Pollution Bulletin 131, 745–756. https://doi.org/10.1016/j.marpolbul.2018.05.006.

Vlachogianni, T., Skocir, M., Constantin, P., Labbe, C., Orthodoxou, D., Pesmatzoglou, I., Scannella, D., Spika, M., Zissimopoulos, V., Scoullos, M. 2020. Plastic pollution on the Mediterranean coastline: Generating fit-for-purpose data to support decision-making via a participatory-science initiative. Science of the Total Environment, 711, 135058. https://doi.org/10.1016/j.scitotenv.2019.135058.

Walther, B. A., Kunz, A., Hu, C.-S. 2018. Type and quantity of coastal debris pollution in Taiwan: A 12-year nationwide assessment using citizen science data. Marine Pollution Bulletin, 135, 862–872. https://doi.org/10.1016/j.marpolbul.2018.08.025.

Web resources

https://caesium.com/cesiumjs/

http://defishgear.izvrs.si/defishgearpublic

https://debristracker.org/

https://docs.google.com/forms/d/e/1FAIpQLSf4chtbaTdJnNKRHTARKFsy8Q1Vham1OiH8mov4OzRe-ot3Vg/viewform

http://hsr-beach.herokuapp.com/login

https://kab.org/programs/cigarette-litter/

https://litterdrone.aebam.org/index.php/proyecto/?lang=en

https://litterintelligence.org/

https://mdmap.orr.noaa.gov/

https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/start-a-cleanup/before-the-cleanup/

https://odims.ospar.org/

https://research.csiro.au/marinedebris/projects/globalplasticsleakageproject/

https://scdhec.gov/environment/your-water-coast/ocean-coastal-management/marine-debris-abandoned-vessels/cigarette

https://uxsrto.research.noaa.gov/News/Articles/ArtMID/6699/ArticleID/979/Marine-Debris-Detection-with-UAS-Machine-Learning-and-Polarimetric-Imaging

http://www.cientificosdelabasura.cl/

https://www.coastalcleanupdata.org/

https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch

https://www.emodnet-chemistry.eu

http://www.environment.gov.il

https://www.kabc.wa.gov.au/campaigns/bin-your-butt

https://www.litterati.org/

https://www.litterati.org/?gclid=Cj0KCQjwraqHBhDsARIsAKuGZeFNTZYrFnEu00JNqzCYxhfG7gAyQFtvgCOkIQcI5yR4YA7OGKCd0Y4aAoa_EALw_wcB

http://www.malic.co.kr/
https://www.mcsuk.org/
https://www.meis.go.kr/portal/main.do
https://www.nmemc.org.cn/
https://www.preventballoonlitter.org/
https://www.unep.org/news-and-stories/story/what-you-need-know-about-plastic-pollution-resolution

7 APPENDICES

7.1 Appendix 1: Reviewed shoreline debris monitoring programs

The basic information of the 31 monitoring programs is summarized in Table A1 to Table A4. Monitoring programs that were initially reviewed but ultimately excluded in this project will be briefly mentioned in the appendix. The inventory consists of 31 monitoring programs that are further categorized by basic information, goals and objectives, targets, scale and scope, data collection and data management. See Tables A1 to A8. The names of the monitoring program listed under "Program" or "Abbreviation" are official names indicated in literature and references. Monitoring programs without an official abbreviated name were arbitrarily given by our researchers. Due to official program names and contents differing over time, literature, and searches on the Web, an expert advisory group should take note of these differences during their review.

"Project/Method" distinguishes whether a monitoring program was executed as a project or as a method simply offering monitoring methodologies. If monitoring programs are carried out as projects, prospective developers of new monitoring programs, such as institutions, countries, etc., will be able to determine if they can join or adopt these projects instead of creating one from scratch. Programs that are denoted as methods indicate that the program only offers monitoring methodologies. Among programs that only offer monitoring methodologies, those that use a mobile app are indicated as "Method (App)." We've distinguished monitoring methods using a mobile app to be easily identified by prospective developers of monitoring programs as these are user-friendly methods. It's worth mentioning that some monitoring programs are difficult to clearly differentiate as a project or a method. For example, Ocean Conservancy's International Coastal Cleanup can be seen as a project or a campaign that widely shares only its monitoring methods. Due to such instances of ambiguity a new category might be needed. Thus, further review will be necessary.

"Lead economy (Region)" indicates the lead entity that has executed, or is executing, the monitoring program along with its geographic information. For instance, if the United States is the lead entity executing a global program, we have indicated this information as USA (Global). "Year Started" denotes the year the monitoring project or method began. "Status" indicates whether or not a monitoring project or method is ongoing. If a project or method is currently ongoing, we've marked it "in progress" for projects, and "in use" for methods. "Reference" indicates the source of the reference.

Table A1. Basic information of nine global or regional monitoring programs

Program (Abbreviations)	Project/ Method	Lead economy (Region)	Year Started	Status	Reference
UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter (UNEP/IOC GSMML)	Method	UNEP/IOC (Global)	2009	In use	Cheshire et al. (2009). UNEP/IOC guidelines on survey and monitoring of marine litter.
MSFD Technical Group on Marine Litter in Europe (EU MSFD TGML)	Method	EU (Regional)	2013	In use	European Commission (2013). Guidance on Monitoring of Marine Litter in European Seas.
EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project (EU MARLIN)	Project	EU (Regional; Baltic Sea: Finland, Sweden, Estonia, and Latvia)	2012	In progress	Miliute-Plepiene et al. (2018) Overview of available methods to monitor marine plastic litter.
Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (EU OSPAR MML)	Project	EU (Regional; Northeast Atlantic Ocean: 11 countries, Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the UK)	2010	In progress	OSPAR (2010) Guideline for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area
Marine Debris Monitoring and Assessment Project (NOAA MDMAP)	Project	USA (Global)	2010	In progress	Burgess et al., (2021). NOAA Marine Debris Monitoring and Assessment Project Shoreline Survey Guide. National Oceanic and Atmospheric Administration Marine Debris Program.
African marine litter monitoring manual (African MLMM)	Project	South Africa	2019	In progress	Barnardo T & Ribbink AJ (Eds.) (2020). African Marine Litter Monitoring Manual. African Marine Waste Network, Sustainable Seas Trust. Port Elizabeth, South Africa

Marine Litter Assessment in the Adriatic & Ionian Seas (MED DeFishGear)	Project	MED (Regional; The Adriatic and Ionian Seas: Albania, Bosnia and Herzegovina, Croatia, Italy, Greece, Montenegro and Slovenia)	2013	Complete	Vlachogianni et al. (2017) Methodology for Monitoring Marine Litter on Beaches Macro-Debris (>2.5cm)
Global Plastic Leakage Baseline Project (GPLBP)	Project	Australia (Global)	2017	In progress	Schuyler et al. (2018b). Handbook of Survey Methodology Plastics Leakage version 1.0
International Coastal Cleanup (ICC)	Project	USA (Global)	1986	In progress	https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/start-a-cleanup/before-the-cleanup/

Table A2. Basic information of 11 domestic level monitoring programs

Program (Abbreviation)	Project/ Method	Lead economy (Region)	Year Started	Status	Reference
China Marine Debris Monitoring Program (China MDMP)	Project	China	2007	In progress	The implementation of the national marine ecological environment monitoring program and quality control program (https://www.nmemc.org.cn)
China National Coastal Cleanup and Monitoring Project (China NCCMP)	Project	China	2014	In progress	Chen et al. (2020) A nationwide assessment of litter on China's beaches using citizen science data.
Indonesia Stranded Beach Debris Program (Indonesia SBDP)	Project	Indonesia	2018	Complete	Cordova (2018). Standard operating procedure monitoring.
Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry (Indonesia MDMG)	Project	Indonesia	2017	In progress	Republic of Indonesia (2020). Marine Debris Monitoring Guideline.
Japan Drifted Beach Debris Monitoring (Japan DBDM)	Project	Japan	2015	In progress	Ministry of Environment, Japan (2019). Report on Comprehensive Examination of Measures Against Drifting Debris (Japanese)
Korea National Beach Litter Monitoring Program (Korea NBLMP)	Project	Korea	2008	In progress	Ministry of Oceans and Fisheries, Korea Marine Environment Management Corporation (2019). Guide to Korea National Beach Litter Monitoring Program
Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline (Viet Nam MAPPL)	Project	Viet Nam	2019	In progress	IUCN Viet Nam and Greenhub (2021). Monitoring and assessment programme on plastic litter in Viet Nam shoreline Report 2019.

The Great British Beach Clean Programme (British BCP)	Project	UK	1994	In progress	Nelms et al. (2020). Investigating the distribution and regional occurrence of anthropogenic litter in English marine protected areas using 25 years of citizen-science beach clean data; https://www.mcsuk.org/
Korea Rapid Assessment (Korea RA)	Project	Korea	2017-2018	Complete	Lee et al. (2019). Rapid assessment of marine debris in coastal areas using a visual scoring indicator.
Chile Litter Scientists (Chile LS)	Project	Chile	2008	In progress	Hidalgo-Ruz et al. (2018). Spatio-temporal variation of anthropogenic marine debris on Chilean beaches.
Israel Clean Coast (Israel CC)	Project	Israel	2005	Complete	Alkalay et al. (2007). Clean-coast index–A new approach for beach cleanliness assessment

Table A3. Basic information of six monitoring programs using mobile apps

Program (Abbreviation)	Project/ Method (App)	Lead economy (Region)	Year Started	Status	Reference
Clean Swell (Clean Swell)	Project	USA (Global)	2016	In progress	https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/cleanswell/
Litterati (Litterati)	Project	USA (Global)	2012	In progress	https://www.litterati.org/?gclid=Cj0KCQjwraqHBhDsARIsAKuGZeFNTZYrFnEu00JNqzCYxhfG7gAyQFtvgCOkIQcI5yR4YA7OGKCd0Y4aAoa_EALw_wcB
University of Georgia's (Marine) Debris Tracker App (MDT)	Project	USA (Global)	2011	In progress	https://debristracker.org/
Marine LitterWatch (EU MLW)	Project	EU (Regional)	2013	In progress	https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch
New Zealand Litter Intelligence (New Zealand LI)	Project	New Zealand (Regional)	2018	In progress	https://litterintelligence.org/
The Australian Marine Debris Initiative (Australia MDI)	Project	Australia (Regional)	2004	In progress	Clark et al. (2021). A visualization tool for citizen-science marine debris big data.

Table A4. Basic information of five monitoring programs using select items

Program (Abbreviation)	Project/ Method (App)	Lead economy (Region)	Year Started	Status	Reference
A Rising Concern: Reducing Balloon Debris through Social Marketing (USA Virginia BL)	Project	USA (Virginia)	2013-2017	Complete	Trapani et al. (2018) Balloon litter on Virginia's remote beach
Disposable Lighter Project (Japan DLP)	Project	Japan (Global)	2003-2004	Complete	Fujieda et al. (2006). Monitoring Marine Debris Using Disposable Lighters as an Indicator.
Cigarette Litter Pilot Project (USA NOAA CLPP)	Project	USA	2015-2016	Complete	https://scdhec.gov/environment/your-water-coast/ocean-coastal-management/marine-debris-abandoned-vessels/cigarette
Bin Your Butt (Australia BYB)	Project	Australia	2019	In progress	https://www.kabc.wa.gov.au/campaigns/bin-your-butt
Cigarette Litter Prevention Program (USA KAB CLPP)	Project	USA	2002	In progress	https://kab.org/programs/cigarette-litter/

Table A5. Goals and objectives of the monitoring programs included in the inventory

Program (Abbreviations)	Goal	Objectives	*Categories of objective
UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter (UNEP/IOC GSMML)	To develop standardized operational guidelines for marine litter surveys and monitoring programs	To quantify and characterize marine debris for the purposes of developing and evaluating the effectiveness of management, control, enforcement and/or mitigation strategies in particular integration with solid waste management; to understand the level of threat posed by marine debris to the biota and ecosystems; and to provide comparable datasets to support domestic, regional and global assessments of marine debris	1, 2, 4
MSFD (EU MSFD TGML)	To provide a basis for the development of management, control, and enforcement measures and to measure the effectiveness of mitigation strategies	To quantify and characterize litter pollution and to provide comparable datasets to support domestic and regional assessments of marine litter	1, 2, 3
EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project (EU MARLIN)	To reduce the negative impact of marine litter	To obtain uniform data, to support litter prevention measures, and to raise public awareness regarding the negative impacts on marine ecosystems	3, 5
Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (EU OSPAR MML)	To minimize the amount of litter entering the marine environment	To provide necessary information based on the OSPAR Regional Action Plan and to guide the development of appropriate actions for reducing marine litter	4

Marine Debris Monitoring and Assessment Project (NOAA MDMAP)	To facilitate a robust and rigorous shoreline marine debris monitoring network that supports research and science-based policies.	To detect spatial and temporal changes in debris loads by material and item type across the US and internationally	2, 3, 4
China Marine Debris Monitoring Program (China MDMP)	To address the problem of marine litter in an effective way	To understand the status of marine debris on shorelines	1, 3
China National Coastal Cleanup and Monitoring Project (China NCCMP)	To elucidate distribution characteristics of beach debris on the coast of China	To investigate the spatial patterns and composition of beach litter along China's coastline; to explore temporal trends in the abundance of plastic litter in one year; to evaluate the impact of major natural and socioeconomic factors, e.g., runoff; and to evaluate data comparability and to provide recommendations for future citizen science efforts in China.	2, 3, 4, 5
Indonesia Stranded Beach Debris Program (Indonesia SBDP)	To reduce the inputs and impact of marine debris on the environment	To obtain necessary data on marine litter for the Indonesian government to manage and control plastic litter and other pollutants at sea	2, 4
Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry (Indonesia MDMG)	To protect and preserve the marine environment from marine debris	To match monitoring methods and to provide guidance to all parties/executors of marine debris monitoring	1, 3

Japan Drifted Beach Debris Monitoring (Japan DBDM)	To reduce the inputs and impact of marine debris on the environment	To understand the amount, distribution, and composition of shoreline debris, and to identify the differences between seas and regions	1, 2, 3
Korea National Beach Litter Monitoring Program (Korea NBLMP)	To gain an understanding of marine debris levels and sources to establish management policies against marine debris	To identify the level, the sources and fate of beach litter, and to provide scientific evidence for policies	1, 2, 3, 4
Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline (Viet Nam MAPPL)	To prevent marine pollution especially plastic pollution	To determine the composition and quantities of plastic waste and its origin; to recommend waste pollution hotspots; to contribute to domestic policy recommendations; to effectively use human and financial resources to minimize and prevent the impacts of marine waste; to fundraise for conservation management activities associated with minimizing plastic pollution	1, 2, 3, 5
The Great British Beach Clean Programme (British BCP)	To understand the scale of the marine anthropogenic litter problem and to inform the development of effective management strategies	To Increase knowledge on the composition, spatial distribution, and temporal trends of coastal debris	1, 2, 3, 4

African marine litter monitoring manual (African MLMM)	To provide a simple, reliable guide for litter monitoring in Africa and beyond	To determine a litter baseline, identify hotspots and sources, develop a litter management strategy, measure change in litter over time, and assess whether the strategy is working	1, 2, 3, 4
Chile Litter Scientists (Chile LS)	To evaluate marine debris densities on the basis of citizen science in Chile	To determine composition, estimate abundance and spatial patterns, and to explore trends of anthropogenic marine debris densities on beaches and from the SE Pacific	1, 2, 3, 5
Marine Litter Assessment in the Adriatic & Ionian Seas (MED DeFishGear)	To set priorities for action and to address marine litter effectively by ensuring sustainable use and management of marine and coastal environments in the Adriatic-Ionian macro region	To get accurate, coherent, and comparable scientific data on marine litter in the Adriatic and Ionian Seas	1, 3, 4
Korea Rapid Assessment (Korea RA)	To understand the spatial distribution and standing stock of marine debris in coastal areas in a cost-effective way	To assess marine debris in geographically broad areas within a short period	1, 2, 3
Israel Clean Coast (Israel CC)	To generate a change in public awareness on the importance of coast cleanliness	To maintain beach cleanliness at all times	4, 5

A Rising Concern: Reducing Balloon Debris through Social Marketing (USA Virginia BL)	To better understand the abundance, distribution, accumulation and fate of balloon-related litter in the marine environment; to decrease the intentional mass release of balloons.	To present information on the accumulation of balloon litter and to help with mitigation efforts in preventing balloon releases	3, 5
Disposable Lighter Project (Japan DLP)	To understand the transport and fate of marine debris using disposable lighters	To estimate the origin of disposable lighters	3, 4
Global Plastic Leakage Baseline Project (GPLBP)	To gain an accurate representation of debris loads in the environment	To understand the distribution of plastic waste along spatial characteristics and to develop a mathematical model to estimate the leakage of marine debris from land to ocean	1, 3
Cigarette Litter Pilot Project (USA NOAA CLPP)	To enhance awareness and to promote proper disposal of cigarette litter on the beach.	To educate and enhance cigarette litter disposal options.	5
Bin Your Butt (Australia BYB)	To reduce cigarette butt litter and its impact on wildlife	To address cigarette butt litter	4
Cigarette Litter Prevention	To find the most effective way to	To reduce cigarette litter.	4

Program (USA KAB CLPP)	address cigarette butts		
International Coastal Cleanup (ICC)	To raise public awareness on the pollution status of marine debris	To keep ocean and waterways clean	1, 2, 3, 4, 5
Clean Swell (Clean Swell)	To enhance public awareness and encourage them to participate in cleanup	To keep beaches, waterways, and the ocean trash free by recording collected debris items	3, 5
Litterati (Litterati)	To contribute to making the world trash free	To empower people to collect litter data and to provide access to that data so that anyone can help create a litter-free world	3, 5
University of Georgia's (Marine) Debris Tracker App (MDT)	To contribute research data to help tackle the plastic pollution crisis	To help citizen scientists make a difference by contributing data on plastic pollution in their community	3, 4, 5
Marine LitterWatch (EU MLW)	To help fill data gaps through beach marine litter monitoring within the framework of MSFD, while raising the public's environmental awareness on marine litter.	To help fill data gaps on relevant beach litter and to explore the benefits of involving citizens in collecting and monitoring marine litter	1, 5

New Zealand Litter Intelligence (New Zealand LI)	To build a "fence at the top of the cliff" to help solve the litter problem	To obtain accurate data to better understand the problem for optimizing solutions and to inspire action for a litter-free world	1, 2, 3, 4, 5
The Australian Marine Debris Initiative (Australia MDI)	To reduce the amount of marine debris washing into our oceans.	To find processes driving the distribution of marine debris, to identify source reduction opportunities, and to communicate science to the public and stakeholders	1, 3, 5

* Categories of objectives are as follows:

1. Identifying baseline status, or pollution levels of shoreline debris
2. Identifying changes over time in the amount, composition, type, and source of debris
3. Conducting a spatial assessment of marine debris (particularly to compare between regions and countries)
4. Providing basic information to develop countermeasures
5. Raising public awareness and building capacity.

Table A6. Target of the monitoring programs included in the inventory

Program (Abbreviations)	Size	Category	Source Identification	All/Select Items	Number of Items
UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter (UNEP/IOC GSMML)	> 2.5 cm	9 materials	Yes	All items	77 items
MSFD Technical Group on Marine Litter in Europe (EU MSFD TGML)	> 2.5 cm, including caps, lids, and cigarette butts	8 materials	Yes	All items	165 items
EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project (EU MARLIN)	> 2.5 cm including cigarette butts/snuff	8 materials (EPS is separated from plastics)	Yes	All items	80 items
Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (EU OSPAR MML)	All litter	11 types	Yes	All items	112 items
Marine Litter Assessment in the Adriatic & Ionian Seas (MED DeFishGear)	> 2.5 cm, including caps, lids, and cigarette butts	8 materials	Yes	All items	159 items
Marine Debris Monitoring and Assessment Project (NOAA MDMAP)	> 2.5 cm	7 materials	Yes	All items	49 items + any approved custom items that nest within the standard hierarchy
China Marine Debris Monitoring Program (China MDMP)	> 6 mm	Types and items	Yes	All items	NA

China National Coastal Cleanup and Monitoring Project (China NCCMP)	> 2.5 cm	6 materials	Yes	All items	64 items
Indonesia Stranded Beach Debris Program (Indonesia SBDP)	> 2.5 cm	7 materials	Yes	All items	42 items
Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry (Indonesia MDMG)	> 2.5 cm	9 materials	Yes	All items	77 items
Japan Drifted Beach Debris Monitoring (Japan DBDM)	> 2.5 cm	9 materials	Yes	All items	95 items
Korea National Beach Litter Monitoring Program (Korea NBLMP)	> 2.5 cm	8 materials	Yes	All items	60 items
Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline (Viet Nam MAPPL)	> 2.5 cm	7 materials	Yes	All items	42 items
The Great British Beach Clean Programme (British BCP)	All visible items	12 materials	Yes	All items	101 items
Korea Rapid Assessment (Korea RA)	All visible items	5 materials	Yes	All items	NA
African marine litter monitoring manual (African MLMM)	> 2.5 cm	11 materials and usages	Yes	All items	153 items
Global Plastic Leakage Baseline Project (GPLBP)	> About 1 cm	13 materials	Yes	All items	Over 84 items
Chile Litter Scientists (Chile LS)	All visible items	5 materials	Yes	All items	NA

Israel Clean Coast (Israel CC)	> 2 cm	2 materials	Yes	All items	NA
International Coastal Cleanup (ICC)	Visible	6 materials	Yes	All items	41+ local specific items
Clean Swell (Clean Swell)	All visible items	7 materials and usages	Yes	All items	44 items
Litterati (Litterati)	All visible items	NA	NA	All items	NA
University of Georgia's (Marine) Debris Tracker App (MDT)	Depends on the project	Depends on the project	Depends on the project	Depends on the project	Depends on the project
Marine LitterWatch (EU MLW)	> 2.5 cm, including caps, lids, and cigarette butts	8 materials	Yes	All items	165 items
New Zealand Litter Intelligence (New Zealand LI)	> 5 mm	9 materials	Yes	All items	110 items
The Australian Marine Debris Initiative (Australia MDI)	All visible items	12 materials	Yes	All items	140 items

Table A7. Scale and scope of the monitoring programs included in the inventory

Program (Abbreviations)	Spatial Scale	Site Characteristics	Number of Sites	Site Selection
UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter (UNEP/IOC GSMML)	Global	A minimum length of 100 m; low to moderate slope of 15º–45º; clear access to the sea; no cleanups; different debris exposures (urban, rural, within close distance to major riverine inputs)	At least 20 sites per region	NA
MSFD Technical Group on Marine Litter in Europe (EU MSFD TGML)	Regional	Sand or rocks/boulders with a slope of 15°-45°; no wide and long mudflat; no cleanups; accessible all year round	NA	Stratified, randomised
EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project (EU MARLIN)	Regional	Larger than 100 m up to 1000 m; 1°-45° slope; sand or gravel for a reference beach; open beach; no cleanups; accessible all year round	23	Structured
Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (EU OSPAR MML)	Regional	Larger than 100 m; sand or gravel; open beach; no cleanups; accessible all year round	ca.70	Structured
Marine Litter Assessment in the Adriatic & Ionian Seas (MED DeFishGear)	Regional	Larger than 100 m; low to moderate slope; no wide and long mudflat; no cleanups; accessible all year round	31	Structured
Marine Debris Monitoring and Assessment Project (NOAA MDMAP)	Global	A continuous section of shoreline at least 100 m in length	About 400 sites at all times; a subset is currently active.	Self-selected or one can implement a representative geographic sample.
China Marine Debris Monitoring Program (China MDMP)	Domestic	Selected from various beaches: sand, gravel, fishing village, port, pre-cleaned shoreline, or uncleaned shoreline	ca. 50	Structured

China National Coastal Cleanup and Monitoring Project (China NCCMP)	Domestic	Larger than 105 m	24 beaches	On demand
Indonesia Stranded Beach Debris Program (Indonesia SBDP)	Domestic	Sandy beach with a slope of 15°-45°; open beach; no cleanups	NA	On demand
Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry (Indonesia MDMG)	Domestic	100 m beach (or 500 m, 1000 m); sand or pebble beach; low-moderate slope (15°-45°); no cleanups; not a sensitive habitat	NA	On demand
Japan Drifted Beach Debris Monitoring (Japan DBDM)	Domestic	NA	12	Structured
Korea National Beach Litter Monitoring Program (Korea NBLMP)	Domestic	Larger than 100 m; sand or gravel; open beach; no cleanups; accessible all year round	60	Structured
Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline (Viet Nam MAPPL)	Domestic	Larger than 100 m; Sand or gravel; Open beach/in MPAs or national parks; No cleanups; Accessible all year round	10	On demand
The Great British Beach Clean Programme (British BCP)	Domestic	Larger than 100 m	Varies by year	On demand
Korea Rapid Assessment (Korea RA)	Domestic	Larger than 100 m; accessible year-round	382	Structured
African marine litter monitoring manual (African MLMM)	Regional	Depends on the survey	Depends on the survey	Random site selection is not recommended
Global Plastic Leakage Baseline Project (GPLBP)	Global	Various characteristics (stratified random site selection)	NA	Structured; random stratified sampling

Chile Litter Scientists (Chile LS)	Domestic	Sand	69 different sites for three years (2008, 2012, 2016)	Structured
Israel Clean Coast (Israel CC)	Domestic	10 m in any kind of beach	39	Structured
International Coastal Cleanup (ICC)	Global	Beach; park; underwater	Numerous sites all over the world	On demand
Clean Swell (Clean Swell)	Global	Depends on the survey	Depends on the survey	On demand
Litterati (Litterati)	Global	Depends on the survey	Depends on the survey	On demand
University of Georgia's (Marine) Debris Tracker App (MDT)	Global	Depends on the project	Depends on the project	Depends on the project
Marine LitterWatch (EU MLW)	Regional	Sand or rocks/boulders with a slope of 15°-45°; no wide and long mudflat; no cleanups; accessible all year round	NA	Structured
New Zealand Litter Intelligence (New Zealand LI)	Regional	Beach, stormwater, freshwater (streams)	Beach (289 sites, New Zealand and Pacific Islands), stormwater (82 sites), freshwater (4 sites)	On demand
The Australian Marine Debris Initiative (Australia MDI)	Regional	Beach	Varies by year	On demand

Table A8. Data collection of the monitoring programs included in the inventory

Program (Abbreviations)	Surveyor	Interval	Training Require-ment	Measurem ent	Using Equipment	Recording Data	Post-Survey Debris Removal	Transects
UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter (UNEP/IOC GSMML)	Varies according to the survey	Annual (minimum); seasonal (recommended)	Varies according to the survey	Number, mass, volume	GPS, data card, camera, balance scale (if weighing)	Data card	Removal	100 m
MSFD Technical Group on Marine Litter in Europe (EU MSFD TGML)	Volunteer or professional	Seasonal	Participate in field trainings for staff and volunteers	Number	GPS, measuring device	Data card, App	Removal	200 m: two 100 m transects for a low to moderately littered beach; or 100 m: two 50 m transects for a heavily littered beach
EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project (EU MARLIN)	Trained volunteer	Seasonal (Excluding winter)	Trained during the first survey	Number (n/m, n/m, n/m^2) is rare	GPS, scale, camera, measuring tape	Data card, Web	Removal	10 m, 100 m, 1,000 m (10 m for small litter such as cigarette/snuff, 100 for >2.5 cm, <50 cm, 1000 m for >50 cm)
Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (EU OSPAR MML)	Volunteer or professional	Seasonal	Obtain advice from experienced field workers; training for field surveyors	Number (n/m)	GPS, scale, camera (cell phone)	Data card	Removal	100 m

			are highly recommended					
Marine Litter Assessment in the Adriatic & Ionian Seas (MED DeFishGear)	Volunteer or professional	Seasonal	Participate in field training for staff and volunteers	n/m^2, kg/m^2	GPS, measuring device	Data card, camera, GPS, measuring tape, scale	Removal	200 m: two 100 m transects for low to moderately littered beach; from the strandline to 10 m back
Marine Debris Monitoring and Assessment Project (NOAA MDMAP)	Trained volunteer or professional	Recommend monthly (28 ± 3 days)	Review online resources and shadow a field surveyor	Number (n/m, n/m^2)	GPS, measuring device (can be a cell phone)	Data card, Web	Removal/ No removal	5 m x 4 in 100 m
China Marine Debris Monitoring Program (China MDMP)	Trained volunteer	Annual	Participate in a training workshop as a team leader	Number and mass (n/km^2, kg/km)	GPS, scale	Data card	Removal	5 m x up to 5 (depending on the length of the coast)
China National Coastal Cleanup and Monitoring Project (China NCCMP)	Trained volunteer	Bimonthly	Participate in a unified training	Number (n/m^2), mass (g/m^2)	Data card	Data card	Removal	5 m x 5 in 105 m
Indonesia Stranded Beach Debris Program (Indonesia SBDP)	Volunteer	Monthly	NA	Number and mass (n/m, g/kg)	GPS, scale, measuring tape, data card, camera (cell phone), rope (>50m)	Data card	Removal	150 m X 3 zones

Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry (Indonesia MDMG)	NA	Biannual (seasonal survey recommended)	NA	Number (n/m^2), mass (g/m^2)	GPS, scale, data card, camera (cell phone)	Data card	Removal	(5 m x 5 m) x5 in 100 m
Japan Drifted Beach Debris Monitoring (Japan DBDM)	Trained volunteer	Annual	NA	Number, mass, and volume	NA	Data card, GPS	Removal	50 m
Korea National Beach Litter Monitoring Program (Korea NBLMP)	Trained paid volunteer	Bimonthly (60 ± 5 days)	Participate in a training workshop annually	Number and mass (n/m, n/m^2, kg/m, kg/m^2)	GPS, scale, measuring tape, data card, camera (cell phone)	Data card	Removal	5 m x 4 in 100 m
Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline (Viet Nam MAPPL)	Trained volunteer	Biannual	Participate in field trainings for staff and volunteers	Number and mass (n/m, kg/m)	GPS, measuring device	Data card	Removal	5 m x 4 in 100 m

The Great British Beach Clean Programme (British BCP)	Volunteer	Annual	Review visual guidelines (surveyor); participate in face-to-face training (organizer)	Items/ m/min/person	GPS, measuring device	Data card	Removal	Between the back of the beach and the strandline
Korea Rapid Assessment (Korea RA)	Volunteer	Seasonal	Participate in a training workshop annually	ℓ/m^2	Smartphone	Data card, App	No removal	One 100 m
African marine litter monitoring manual (African MLMM)	Trained surveyor	Seasonal	Providing manual	/m, g/m	PS, scale, data card	Data card	Standing stock survey: optional, accumulation survey: mandatory	100 m for standing stock, 500 m for accumulation
Global Plastic Leakage Baseline Project (GPLBP)	Trained volunteer	Recommended pre and post rainy seasons	Participate in field trainings	Number (for standing stock surveys) (n/m, n/m^2)	GPS, data card	Data card	No removal	2 m x 3-6 transects
Chile Litter Scientists (Chile LS)	Trained volunteer	Once a year for three different surveys	Conduct several preparatory activities or a dry run of AMD (anthropogeni	n/m^2	GPS, measuring device	Data card, Web	Removal	(3 m x 3 m) 6-30 quadrats in a site

			c marine debris) surveys for all participants					
Israel Clean Coast (Israel CC)	Public officers; volunteer	Twice a month for 6 months	NA	n/m^2	NA	NA	Removal	2 m x 5 in 10 m
International Coastal Cleanup (ICC)	Volunteer	Globally conducted	Obtain an instruction guide from a coordinator (online or field)	Number	GPS, data card	Data card	Removal	No limit
Clean Swell (Clean Swell)	Volunteer	Opportunistic	Provide survey manual (leaflet, web video)	Number	Smartphone	App	Removal	NA
Litterati (Litterati)	Volunteer	Opportunistic	Provide survey manual (web video)	Number	Smartphone	Web	NA	NA
University of Georgia's (Marine) Debris Tracker App (MDT)	Volunteer	Opportunistic	Provide survey manual (web video)	Number	Smartphone	App	Depends on the project	Depends on the project
Marine LitterWatch (EU MLW)	Volunteer or professional	Seasonal	Provide survey manual (web)	Number	Smartphone	App	Removal	100 m

New Zealand Litter Intelligence (New Zealand LI)	Trained volunteer or professional	Seasonal	Participate in a training workshop; provide survey manual (web video)	Number (n/m^2), mass (g/m^2), Volume (estimate of total liters)	GPS or smartphone, data card, camera, scale, sieve (to exclude items < 5 mm)	Data card, web	Removal	One 20 m x 100 m
The Australian Marine Debris Initiative (Australia MDI)	Volunteer	Opportunistic	Provide survey manual (web video)	Number	Smartphone	App/Web	Removal	Varies by survey

Table A9. Management of the monitoring programs included in the inventory

Program (Abbreviations)	Quality Management	Database	Data Analysis
UNEP/IOC Guidelines on Survey and Monitoring of Marine Litter (UNEP/IOC GSMML)	Training surveyors; providing pictorial field guides	NA	NA
MSFD Technical Group on Marine Litter in Europe (EU MSFD TGML)	Data cleaning after data aggregation	https://www.emodnet-chemistry.eu	In-house specialist
EU Marine Litter in the Baltic Sea and Baltic Marine Litter Project (EU MARLIN)	Providing manuals and training for coordinators (coordinators are in charge of training the participants)	http://hsr-beach.herokuapp.com/login	In-house specialist
Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (EU OSPAR MML)	Providing training for field workers is highly recommended	https://odims.ospar.org/	In-house specialist
Marine Litter Assessment in the Adriatic & Ionian Seas (MED DeFishGear)	Checking and data cleaning all raw data for errors before analyzing	http://DeFishgear.izvrs.si/DeFishgearpublic	In-house specialist
Marine Debris Monitoring and Assessment Project (NOAA MDMAP)	Data submitted to a data portal and verified before publication; consistency checks completed in the field once a year	https://mdmap.orr.noaa.gov/	In-house specialist
China Marine Debris Monitoring Program (China MDMP)	Training for coordinators and surveyors (separately)	NA	In-house specialist
China National Coastal Cleanup and Monitoring Project (China NCCMP)	Training surveyors	NA	In-house specialist
Indonesia Stranded Beach Debris Program (Indonesia SBDP)	NA	NA	In-house specialist
Indonesia Marine Debris Monitoring Guidelines from Ministry of Environment and Forestry (Indonesia MDMG)	NA	NA	NA

Japan Drifted Beach Debris Monitoring (Japan DBDM)	NA	NA	In-house specialist
Korea National Beach Litter Monitoring Program (Korea NBLMP)	Manuals and training (provided by contractors); conducting joint surveys; photographs; downloading data from the database and checking probable errors in person and, if any, corrected immediately	https://www.meis.go.kr/portal/main.do	In-house specialist
Viet Nam Monitoring and Assessment Program on Plastic Litter in Viet Nam Shoreline (Viet Nam MAPPL)	Training	NA	In-house specialist
The Great British Beach Clean Programme (British BCP)	Validating data by a survey coordinator (subject to further quality control by MCS)	https://www.mcsuk.org/	In-house specialist
Korea Rapid Assessment (Korea RA)	Validating data by a survey coordinator	http://www.malic.co.kr/	In-house specialist
African marine litter monitoring manual (African MLMM)	Providing manuals and training surveyor	NA	NA
Global Plastic Leakage Baseline Project (GPLBP)	Providing manuals and training for coordinators	https://research.csiro.au/marinedebris/projects/globalplasticsleakageproject/	In-house specialist
Chile Litter Scientists (Chile LS)	Distributing guidelines and providing education for students	http://www.cientificosdelabasura. cl/	In-house specialist
Israel Clean Coast (Israel CC)	NA	http://www.environment.gov.il	In-house specialist
International Coastal Cleanup (ICC)	Distributing manuals or conducting activities with coordinators	https://www.coastalcleanupdata.org/	Open DB

Clean Swell (Clean Swell)	NA	https://www.coastalcleanupdata.org/	Open DB
Litterati (Litterati)	NA	https://www.litterati.org/	Open DB
University of Georgia's (Marine) Debris Tracker App (MDT)	Depends on the project	https://debristracker.org/	Open DB
Marine LitterWatch (EU MLW)	Data cleaning after data aggregation	https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/marine-litterwatch	Online tool for a customized analysis
New Zealand Litter Intelligence (New Zealand LI)	Training surveyors Providing standardized equipment. Validating data by a survey coordinator. QC/consistency checks completed at 10% of sites. Full QAQC and training documentation available online.	https://litterintelligence.org/data/	Open DB and online tool for a customized analysis
The Australian Marine Debris Initiative (Australia MDI)	Data control by Tangaroa Blue	https://caesium.com/cesiumjs/	Online tool for a customized analysis

7.2 Appendix 2: Monitoring methodologies excluded

There are two monitoring methodologies of NOWPAP (2007) and HELCOM (2008) which are not included in the list of monitoring programs in Appendix 1. NOWPAP (2007) has published a guideline by compiling information on shoreline marine debris monitoring in the Northwest Pacific region, but its publication has yet to lead to any actual monitoring. HELCOM (2008) has also released a recommendation on monitoring methods and actual surveys are implemented in various EU monitoring programs (e.g., EU MARLIN). Although excluded from the tables above, monitoring using new technologies is also likely to be helpful and is shown in Table A10.

Table A10. Introduction to two monitoring methodologies excluded in Chapter 2

Program	Spatial scale	Included or not	Reason for exclusion
HELCOM Baltic Sea Action Plan	Baltic Sea Region	Not included	Review of other protocols
NOWPAP	NOWPAP countries	Not included	Compilation of monitoring data in NOWPAP areas