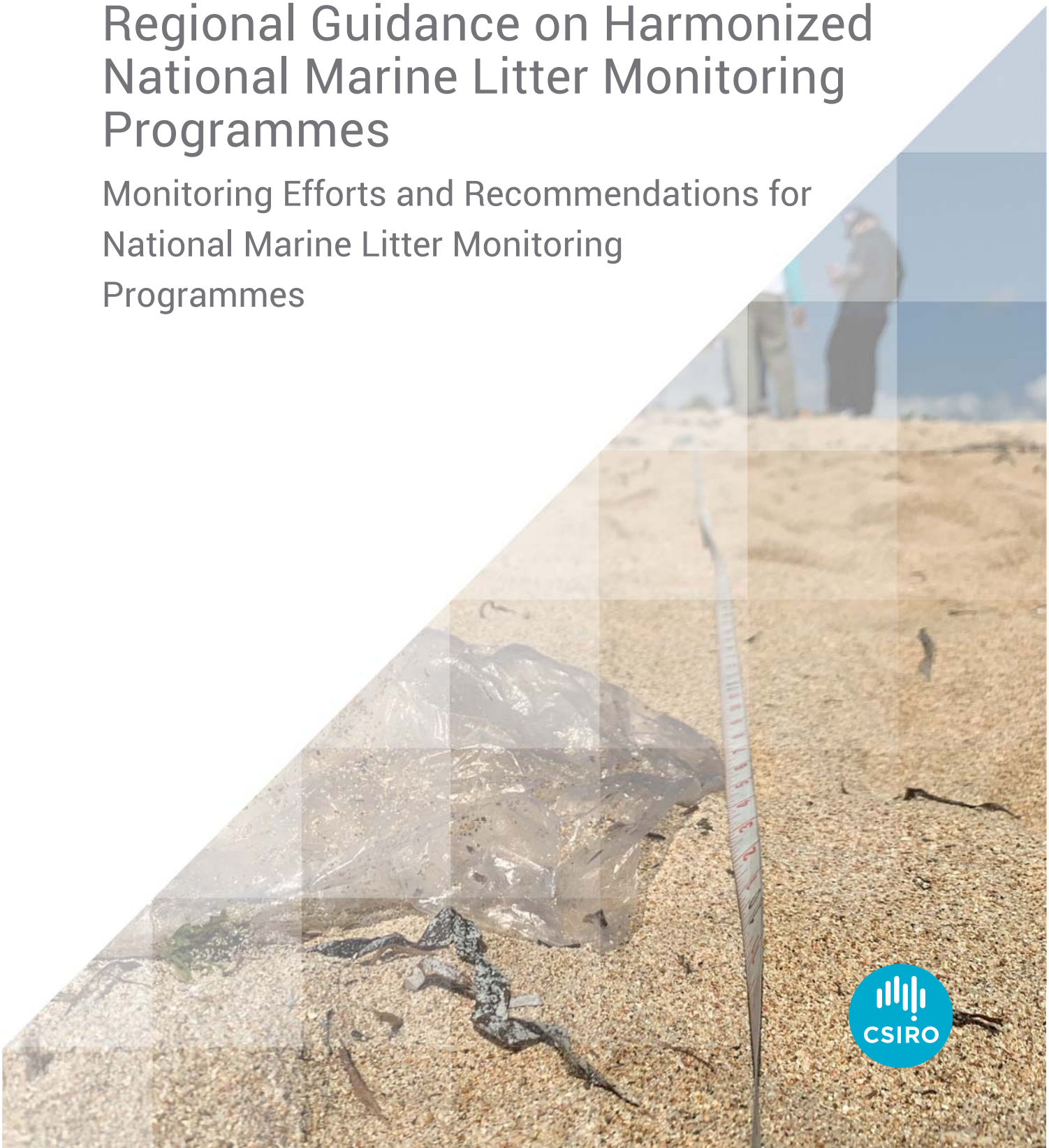
UN environment programme 50 1972-2022

COBSEA
COORDINATING BODY ON THE SEAS OF EAST ASIA

Regional Guidance on Harmonized National Marine Litter Monitoring Programmes

Monitoring Efforts and Recommendations for National Marine Litter Monitoring Programmes



Suggested citation

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.

Disclaimer

Acknowledgments

This document was developed as part of the SEA circular project – Reducing marine litter by addressing the management of the plastic value chain in South-East Asia implemented by the United Nations Environment Programme (UNEP) and the Coordinating Body on the Seas of East Asia (COBSEA), with support from the Government of Sweden.

This document provides Regional Guidance on Harmonized National Marine Litter Monitoring Programmes to strengthen and harmonize marine litter monitoring efforts toward preventing and reducing marine litter and its impacts, in line with the COBSEA Regional Action Plan on Marine Litter (RAP MALI). The review responds to the needs identified by COBSEA participating countries, incorporates country contributions, and builds on existing capacities and priorities, to promote data comparability and align efforts at regional and global level. The document was prepared by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the COBSEA Secretariat, in close consultation with COBSEA participating countries and with guidance from the COBSEA Working Group on Marine Litter.

Lead authors
Britta Denise Hardesty and Lauren Roman, CSIRO

Contributors
Natalie Harms (editor) and Jerker Tamelander, COBSEA Secretariat, UNEP

Photo credits: Natalie Harms

We gratefully acknowledge the following contributors from COBSEA participating countries:
Kim Nong, Monomoyith Than, Chantha Sreng and Bianca Roberts (Fauna & Flora International, SEA circular partner) and collaborators in Cambodia;
Pei Xiangbin, Liu Guozhi, Yu Yunjun, Daoji Li and collaborators in China;
Novy Farhani, Reza Cordova, Endang Linirin Widiastuti, Kiki Prio Utomo, Agus Supriyanto, Iyus Sari Nurhusnah, Devi Dwiyanti S., I Gede Hendrawan (Udayana University), Tuti hadiputranto and collaborators in Indonesia;
Keun-Hyung Hong, Bok-young Song, Minsup Shin, Juyoung Park and collaborators in the Republic of Korea;
Eddy Mazuaansyah Bin Mohd Ali Murad, Malisa Mat Noor, Cheryl Rita Kaur, Jacqueline Chang Li Ching and collaborators in Malaysia;
Vizminda A. Osorio, Michiko Sibunga, Likha Alcantara and collaborators in the Philippines;
Siti Aisyah binte Mohamad Firoz, Simret Kaur, Cheo Pei Rong and collaborators in Singapore;
Supawat Kan-atireklap, Orathai Pongruktham and collaborators in Thailand;
Anh-Duc Luu, Tran Van Hung, Quan Dam (SEA circular consultant), Emilie Strady (Institut de Recherche pour le Développement, France) and collaborators in Viet Nam.

The **United Nations Environment Programme (UNEP)** is the leading global voice on the environment. UNEP provides leadership and encourages partnership in caring for the environment by inspiring, informing and enabling nations and peoples to improve their quality of life without compromising that of future generations. The UNEP Regional Office for Asia and the Pacific is working to support prosperity, build resilience and boost resource efficiency across the region and is located in Bangkok. www.unep.org

The **Coordinating Body on the Seas of East Asia (COBSEA)** is a regional intergovernmental mechanism and one of 18 Regional Seas programmes. It is the decision-making body for the East Asian Seas Action Plan, bringing together nine countries – Cambodia, China, Indonesia, Republic of Korea, Malaysia, the Philippines, Thailand, Singapore and Viet Nam – in protection and sustainable development of the marine and coastal environment. COBSEA focuses on marine pollution, ecosystem-based marine and coastal planning and management, and ocean governance. The COBSEA Secretariat is hosted by Thailand in Bangkok and administered by UNEP Ecosystems Division in Nairobi.
www.cobsea.org **|** unep-cobsea@un.org

The **Commonwealth Scientific and Industrial Research Organisation (CSIRO)** is Australian Government's national science research agency responsible for scientific and industrial research. CSIRO aims to solve the greatest challenges using innovative science and technology by using science to solve real issues to unlock a better future for our community, our economy, our planet. From its headquarters in Canberra, CSIRO works with leading organizations around the world and maintains more than 50 sites across Australia and in France, Chile and the United States. www.csiro.au

The **SEA circular** project – Reducing marine litter by addressing the management of the plastic value chain in South-East Asia is implemented by the United Nations Environment Programme (UNEP) Regional Office for Asia and the Pacific and the Coordinating Body on the Seas of East Asia (COBSEA), with support from the Government of Sweden. SEA circular aims to reduce and prevent plastic pollution and its impact by working with governments, businesses, civil society, academia, and international partners. The initiative promotes market-based solutions and enabling policies to transform plastic value-chain management, strengthens the science base for informed decision making, creates outreach and awareness. The project leverages COBSEA's regional mechanism to tackle the transboundary challenge of marine litter in a harmonized manner.
www.sea-circular.org **|** sea-circular@un.org

List of abbreviations

ALDFG - Abandoned Lost or otherwise Discarded Fishing Gear
ASEAN - Association of Southeast Asian Nations
BACI - Before-After-Control-Impact
COBSEA - Coordinating Body on the Seas of East Asia
CSIRO - The Commonwealth Scientific and Industrial Research Organisation
GESAMP - Group of Experts on the Scientific Aspects of Marine Environmental Protection
GPLP - Global Plastics Leakage Project
IOC-UNESCO - Intergovernmental Commission on Oceanography of the United Nations Educational, Scientific and Cultural Organization
ICC - International Coastal Clean-up
IGM - Intergovernmental Meeting of COBSEA
NGO - Non-government organization
MDMAP - Marine Debris Monitoring and Assessment Project (NOAA)
MSFD - Marine Strategy Framework Directive (European Union)
NOAA - National Oceanic and Atmospheric Administration (United States of America)
NOWPAP - Northwest Pacific Action Plan
OC ICC - The Ocean Conservancy's International Coastal Clean-up programme
OSEAN - Our Sea of East Asia Network
PA DAD - PADI AWARE Dive Against Debris programme
RAP MALI - COBSEA Regional Action Plan on Marine Litter (2019)
UNEP - United Nations Environment Programme
WGML - COBSEA Working Group on Marine Litter

Contents

Acknowledgments ii
List of abbreviations iv

Background and rationale 1

1 Marine litter monitoring in the East Asian Seas 1
2 What is the purpose of this document and how was it compiled? 2

Part I Review of monitoring, survey designs and methodologies 5

3 What is marine litter monitoring? 6
4 Why monitor or survey marine litter? 6
4.1 Marine litter monitoring programmes 7
4.2 One-off marine litter survey programmes 7
5 Habitats 8
5.1 Shorelines and coastal environments 9
5.2 Rivers and waterways 9
5.3 Oceans (sea surface, water column and seafloor) 10
5.4 Biota 10
6 Survey design 11
6.1 Balanced surveys to account for potential variables 11
6.2 Avoiding bias in site selection 11
6.3 Within-site replication 11
6.4 Sampling hierarchy if predicting outside observed conditions 12
7 Use of citizen science marine litter surveys 12
7.1 Incorporating citizen science into marine litter monitoring 12
8 Examples of global marine litter monitoring programmes 13
8.1 Ocean Conservancy International Coast clean-up (ICC) 14
8.2 PADI AWARE Dive Against Debris 14
8.3 National Oceanic and Atmospheric Administration Standing Stock Surveys 14
8.4 CSIRO Global Plastics Leakage Project (GPLP) 14
8.5 Survey design in global marine litter monitoring programmes 14
9 Science-based best practice approaches to marine litter monitoring 15
9.1 Summary of survey design suggestions 15

Part II Inventory of monitoring efforts in COBSEA countries 20

10 What is currently being done in COBSEA countries? 21
10.1 Timelines 21
10.2 Compiling an inventory of marine litter monitoring efforts to inform regional guidance 22
10.3 One-off surveys and published outputs of previous one-off activities 22

10.4 Ongoing monitoring programmes 25
10.5 Summarizing existing monitoring activities 32
10.6 Reviewing ongoing monitoring activities in COBSEA countries 33
10.7 Successes, gaps, and opportunities in COBSEA monitoring activities..... 35

Part III Recommendations for harmonizing marine litter monitoring 36

11 General recommendations for COBSEA participating countries 37
11.1 Recommendations overview 37
11.2 Attention to timing of surveys 37
11.3 Attention to surveys that include litter that may enter waterways and move to the coastal/marine environment 38
11.4 Attention to reporting survey effort across monitoring programmes 38
11.5 Attention to aligning the data reporting categories of national monitoring programmes 38
11.6 Adoption and expansion of programmes already operating in the region that fulfil the five tenets for designing national and regional scale marine litter monitoring programmes 39
11.7 Programmes that fulfil the five tenets for designing national and regional scale marine litter monitoring programmes in biota 40
12 Specific recommendations for programmes currently conducted across multiple COBSEA participating countries 42
12.1 Representative survey design recommendations for implementation of Ocean Conservancies 'International Coastal clean-up' programme (Coastlines) 42
12.2 Representative survey design recommendations for implementation of PADI AWARE's Dive Against Debris programme (Ocean - seafloor) 44

Annex 1. COBSEA regional monitoring inventory sheet[1]

[1] The inventory is available as a separate spreadsheet on the COBSEA website.

Background and rationale

1 Marine litter monitoring in the East Asian Seas

Pollution of the world's oceans by plastic and other anthropogenic solid waste is a transboundary problem. Plastic production, and the consequent loss of plastic solid waste to the environment is growing through time (Lebreton and Andrady, 2019), which is reflected in the growing amount of 'marine litter', predominantly plastic, on the ocean's surface (Wilcox et al., 2020). The United Nations Environment Programme (UNEP) defines 'marine litter' as "[…] any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment". The focus of this review is on plastic marine litter, though the term maybe used interchangeably with 'marine debris' by some entities.

In 2016, more than 10% of the global production of plastic, approximately 19 to 23 million metric tons, was estimated to have entered aquatic ecosystems (Borrelle et al., 2020). Plastic in marine and aquatic environments is more than an eyesore. This waste negatively impacts wildlife health through ingestion (Roman et al., 2019; Wilcox et al., 2018) and entanglement (Wilcox et al. 2013; Parton et al. 2019), poses a hazard to marine logistics and transport, and is potentially a human health issue (Wright and Kelly, 2017). Despite increasing global awareness of plastic pollution and rising multijurisdictional momentum seeking and effecting changes at local and national levels, there remain significant challenges to developing meaningful solutions at broader scales.

Mismanaged plastic waste is predicted to increase over the coming decades in quantities that far exceed the current mitigation efforts (Borrelle et al., 2020). Countries in Asia, in particular, are forecast to be disproportionate sources of this plastic waste entering the ocean through rivers in the coming years (Lebreton and Andrady, 2019) and had been previously identified as some of the top countries where plastic leaked to the marine environment (Jambeck et al. 2015). To address the risk that mismanaged plastic waste poses to coastal and marine systems, the first step is quantifying and understanding the nature of the pollution problem. Mismanaged waste in the marine environment is heterogeneous and transboundary by nature, driven by both socioeconomic and geographic factors (Hardesty et al. 2021). Quantifying and measuring the extent and change in this heterogeneous environmental problem is forefront to identifying plastic sources and sinks and implementing effective solutions. Instituting pollution monitoring programmes at regional scales is one of many important approaches to solving the global plastic pollution crisis.

In 2019, the Twenty-fourth Intergovernmental Meeting of the Coordinating Body on the Seas of East Asia (COBSEA) revised and adopted the COBSEA Regional Action Plan on Marine Litter (RAP MALI). The RAP MALI guides coordinated action in the East Asian Seas region toward preventing and reducing marine litter from land-based sources (Action 1) and from sea-based sources (Action 2), strengthening monitoring and assessment of marine litter (Action 3), and creating enabling conditions for implementation (Action 4). The RAP MALI has the explicit objective to "improve monitoring and assessment of marine litter and its impacts for a science-based approach" (Objective 4).

The COBSEA RAP MALI recognizes that robust monitoring and assessment are indispensable in identifying marine litter status and trends and its most critical impacts, and to support development, tracking and evaluation of policy and management interventions. To improve knowledge on the main types, sources and amounts of litter that enter the marine and coastal environment in line with globally established guidelines, RAP MALI Appendix 2, key action 3.2.1. suggests to "prepare regional guidance on the development of harmonized National Marine Litter and Microplastic Monitoring Programmes, in line with globally established guidelines."

2 What is the purpose of this document and how was it compiled?

COBSEA Regional Guidance on Harmonized National Marine Litter Monitoring Programmes directly addresses regional priorities collectively identified by COBSEA countries, responds to existing monitoring efforts and capacities in participating countries, was developed in a consultative process with contributions from participating countries, and considers the needs and context of individual countries. Recommendations provided are both regionally appropriate and in line with globally established guidelines, methods, and quality standards. The aim of this document is to strengthen national monitoring programmes building on existing capacities and priorities as identified in the RAP MALI, while promoting data comparability and aligning efforts at regional and global level. Greater harmonization of monitoring methods corresponds with discussions of the ad hoc open-ended expert group on marine litter and microplastics (AHEG) at its fourth meeting on 9-13 November 2020 (UNEP/AHEG/4/7). Developing regional-level guidance on harmonization provides targeted recommendations for application of global guidelines tailored to national and regional context and leverages existing regional mechanisms such as COBSEA to accelerate global progress on addressing the transboundary challenge of marine litter in a harmonized manner.

The COBSEA Working Group on Marine Litter (WGML) recognized that marine litter monitoring is being pursued based on nationally identified priorities and needs, and with consideration of national context. Harmonization of national marine litter monitoring programmes does not entail establishing identical monitoring programmes across all countries. Rather, harmonization and better data comparability can be pursued through definition of specific common objectives addressed through national monitoring programmes. Furthermore, common core indicators, associated recommended methods and data standards that are identified and agreed at regional level International guidance will support such efforts. These include the 2019 report of the Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) on 'Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean' (Kershaw et al., 2019) and similar efforts of Regional Seas programmes, such as the Northwest Pacific Action Plan (NOWPAP) 'Report on Implementation of the NOWPAP Regional Action Plan on Marine Litter in 2018-2019' (Plan, 2020).

The technical consultation of the COBSEA WGML on 23-25 June 2020 identified steps towards harmonized marine litter monitoring, in line with the RAP MALI:

- Establish an inventory of existing marine litter monitoring efforts;
- Establish a Marine Litter Monitoring Expert Group under COBSEA WGML;
- Establish common objectives for marine litter monitoring in the context of COBSEA RAP MALI;
- Identify proposed common indicators, recommended methods and data standards; and

- Capacity building.

Accordingly, COBSEA partnered with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) to map monitoring efforts in the region and prepare Regional Guidance on Harmonized National Marine Litter Monitoring Programmes in the East Asian Seas for discussion in the WGML and consideration by the Twenty-fifth Intergovernmental Meeting of COBSEA.

CSIRO and the COBSEA Secretariat also carried out a review of current (at the time of compiling) monitoring efforts in the region to highlight similarities and differences among approaches and a review of best practices and main recommendations from global guidelines, reports and peer-reviewed publications for science-based marine litter monitoring, establishing baselines, and monitoring changes over time. A series of webinars were held in 2020 and 2021 to consult COBSEA participating countries, seek country input on existing monitoring efforts, and validate the regional inventory and identified recommendations. The Third Meeting of the WGML on 29-30 June 2021 finalized the Regional Guidance document and recommended it for adoption. The WGML further established an Expert Group on Monitoring to support implementation of Regional Guidance.

The Regional Guidance on Harmonized National Marine Litter Monitoring Programmes was adopted by the first part of the Twenty-fifth Intergovernmental Meeting of COBSEA by silence procedure on 12 November 2021.

The document herein compiles and compares existing monitoring efforts in COBSEA participating countries (as provided by countries) and provides targeted recommendations for sound marine litter monitoring and toward regional harmonization. Recommendations focus on practical guidance to adapt current marine litter monitoring programmes and efforts and employ science-based best practice approaches for improved outcomes, following recognized guidelines of the GESAMP report (2019). This report is not intended as a top-down set of instructions to restructure national monitoring efforts, but rather a collaboration between participating countries seeking to make changes for improved outcomes toward regional harmonization of monitoring approaches.

This Regional Guidance acknowledges that national marine litter monitoring programmes are under different stages of development in the region and significant variation may exist in terms of indicators and methods used, depending on nationally identified priorities and capacities. Monitoring strategies serve different purposes and are tailored to different types of research questions relevant to national context. For example, some marine litter monitoring projects may seek to understand the impacts on wildlife, while others may be designed to monitor the effectiveness of policies under consideration or implementation or may aim to increase community awareness and engagement (or some combination therein). It is important to ensure that a monitoring programme meets targets or objectives identified by countries, and to acknowledge that those goals may change over time.

The RAP MALI recognizes the need for increasing coherence, coordination and synergies between existing mechanisms and to enhance cooperation and governance to better address marine litter at local, national, regional and global levels, including coordination across (sub)regional policy frameworks such as the Association of Southeast Asian Nations (ASEAN). Bearing in mind the large

overlap in country composition of COBSEA and ASEAN, this guidance on harmonization can be leveraged to support national and regional efforts related to the ASEAN Framework of Action on Marine Debris, to reduce duplication and reporting burdens for countries.

This document includes:

- A review of marine litter survey and monitoring methodologies and good practices (Part I),
- A regional inventory of marine litter monitoring efforts underway in COBSEA countries, and organizations involved (Part II);
- A review of monitoring programmes to determine whether they follow a science-based approach and are likely to achieve national monitoring objectives (Part II);
- Recommendations to strengthen and harmonize existing monitoring methodologies and approaches to improve outputs (Part III).

Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) on 'Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean'

In 2019, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection, a group of independent scientific experts that provides advice to the United Nations system on scientific aspects of marine environmental protection, tabled the "Guidelines for the monitoring and assessment of plastic litter in the ocean" or GESAMP report.

The principal purpose of the GESAMP report was to provide recommendations, advice, and practical guidance, for establishing programmes to monitor and assess the distribution and abundance of plastic litter, also referred to as plastic debris, in the ocean. It is a product of the GESAMP Working Group (WG40) on 'Sources, fate and effects of plastics and microplastics in the marine environment', co-led by the Intergovernmental Commission on Oceanography (IOC-UNESCO) and UNEP. The report was prepared by 19 independent experts from 14 countries, with financial support from a number of agencies and national governments.

The intention of the GESAMP report is to promote a more harmonized approach to the design of sampling programmes, the selection of appropriate indicators (i.e. type of sample), the collection of samples or observations, the characterization of sampled material, dealing with uncertainties, data analysis and reporting the results. The GESAMP report guidelines cover all size ranges of plastic litter encountered in the marine environment, on shorelines, floating on the sea surface, suspended in the water column, deposited on the seabed or associated with biota (ingested/encrusted/entangled). The GESAMP report guidelines may be used for the monitoring of items originating from specific sources (e.g. Abandoned Lost or otherwise Discarded Fishing Gear, ALDFG) or specific items to evaluate the efficiency of dedicated reduction measure (e.g. single-use consumer plastics, sanitary related items).

Part I Review of monitoring, survey designs and methodologies

Part I of this report introduces different types of marine litter surveys and monitoring methodologies. This section highlights key facets to consider when designing marine litter surveys or monitoring programmes to guide future monitoring and survey efforts.

3 What is marine litter monitoring?

"Marine litter monitoring", as adapted from The United Nations Environment Programmes' Evaluation Manual (2008) definition of monitoring, is the regular collection and analysis and distribution of information for the surveillance of plastic and other anthropogenic litter in marine, coastal and aquatic environments.

These data, when analysed, can aid in identifying marine litter baselines, changes, the progress or limitations of interventions or management activities as early as possible. Such data can support governing bodies, project managers and communities to implement or adjust management actions or activities as needed. Monitoring is a continuing process throughout time and/or space or throughout the implementation of a project or management plan. Often, monitoring programmes are initiated, and paused, though the benefit of the effort may extend beyond completion. Single or "one-off" data collection efforts, or 'surveys' do not constitute marine litter monitoring. However, a collection of one-off survey efforts, if appropriately harmonized, can feed into one national programme or source inventory.

Furthermore, every monitoring programme begins with an initial or 'one-off' effort. It is when such initial efforts (which may start with a baseline survey effort) are continued, that a monitoring programme has begun.

4 Why monitor or survey marine litter?

Why monitor or survey marine litter? Having an answer and specific outcome in mind and an answer to this question is the premier consideration for designing a programme. Having clarity on the goal or purpose is primary and sits at the top of the hierarchy when designing a marine litter monitoring programme. Once there is clarity of purpose, selecting the best approach which will answer the questions and address the goal or purpose becomes more straightforward.

Common reasons for embarking on marine litter monitoring programmes include:

- Looking at the changes in quantity and/or composition of marine litter through time;
- Facilitate decision making with respect to marine litter;
- Understanding whether there are problem litter items in your local region;
- Understanding the sources and sinks of marine litter in your region;
- Understanding movement of litter within a or between regions;
- Understanding how marine litter in your local area compares to other areas.

The information gained from monitoring programs is increasingly gathered for the purpose of informing policy decisions to reduce inputs to the coastal and marine environment. The reduction of marine litter is a goal sought to improve quality of life for humans and wildlife, for example:

- Maintaining a beautiful environment. Marine litter can be an eyesore and reduces the economic and perceived intrinsic value of an area;
- Protecting the environment;
- Safeguarding human health;
- Conservation of wildlife.

However, all marine litter surveys are not equal in the quality of data that they can provide to fulfil the above goals. Survey design is a key component in developing a quality data set. It is useful to consider design at multiple levels, whether embarking on a new, or modifying an existing programme. Marine litter monitoring programmes can be ongoing programmes, or may commence with one-off surveys, often with a specific goal in mind. These two approaches are designed in very similar ways, but there are some key differences between them. It is important to understand that one-off surveys often form the basis for ongoing monitoring programmes, and that both survey types are valuable and informative to programme managers and policy makers.

Suitability of Plastic Pollution Assessment Methodologies (SPAM) toolkit
Need help identifying or narrowing down 'what is my objective' and 'which methods are best suited towards meeting my objective'? The "Suitability of Plastic Pollution Assessment Methodologies (SPAM)" toolkit, developed by the World Bank in collaboration with external contributors may be a useful place to look, as will be the GESAMP guidelines.

4.1 Marine litter monitoring programmes

Marine litter monitoring programmes are ideally conducted on an on-going basis. Marine litter monitoring programmes are the most useful approach to assess changes through time and responses to policy change, given that they will optimally provide long-term information about debris density, distribution and changes in the focal area. Marine litter monitoring programmes are often funded by government, non-government organizations or a private entity that has access to ongoing funding. Sometimes there is a specific policy-related goal associated with a monitoring programme, others are designed to prioritize environmental health through the removal of litter, while others may focus on fostering to community spirit. Ongoing litter monitoring programmes may be conducted daily, weekly, monthly, six-monthly, annually, or even bi-annually.

4.2 One-off marine litter survey programmes

Some marine litter surveys occur just one once, or several times across a fixed duration, and are usually designed with an end goal in mind. For example, a survey designed around a research question, such as the amount of litter in a particular waterway, or to test the effectiveness of a policy change, such as a grocery bag ban. While one-off surveys do not constitute a monitoring programme, a collection of one-off survey efforts, if appropriately harmonized, can feed into one national programme or source inventory, and are included as valuable resources in this report.
Many university studies and research programmes are one-off marine litter survey programmes, though these programmes might involve multiple surveys throughout a fixed period. Funding to undertake the litter surveys may be linked to a particular outcome. Though one-off marine litter surveys are often not the best tool to examine long-term time trends, they are ideal for situations where there are resources available to achieve a specific goal. The data from one-off surveys can provide useful snapshots of litter in a habitat or region though, and longer-term litter monitoring programmes may be instigated by the results of one-off surveys.
If the goal of a one-off marine litter survey programmes is to monitor the success of a policy, we recommend that the survey incorporate a Before–After-Control–Impact (BACI) design (Conner et

al., 2015). BACI designed studies are ideal to look at changes in litter or marine debris before and after a policy has been implemented or another local change has taken place (such as more bins, drink refill stations or plastic bag bans).

Situations where a BACI designed survey might be utilized:

- To monitor the effectiveness of policy change (such as introduction of a new waste facility or prohibition on a type of single use plastic)
- To monitor the outcome of a land-use change (such as a new housing development);
- To monitor the change, if any, of litter in areas where a new park or additional waste bins have been located.

Before–After-Control–Impact (BACI) design of surveys seek to assess local changes in marine litter:

1. Identify two types of sites: those that will be subjected to the disturbance, the "impact" site; and those that will not, the "control" site;
2. Choose multiple sites within each of the "impact" and "control" regions (replication) to conduct surveys, surveying the variables of interest at all sites (for example, the number of plastic bags and other litter before a plastic bag ban);
3. Conduct the same type and number of surveys within the each of the "impact" and "control" regions both before the intervention/impact takes place and after the intervention/impact takes place

Improvements to BACI designs:
Sometimes single "control" or "impact" sites can be subject to unexpected changes (for example, if a flood affects the site). To overcome this potential issue, monitor multiple sites of each type if possible, and conduct multiple surveys before and after the disturbance. This is sometimes called a 'multiple before-after-control-impact' (M-BACI) design.

One-off litter surveys often form the basis for ongoing monitoring programmes and can provide valuable snapshots of litter in time and space. This information can feed into and form the basis of a data-driven foundation for policy or decision making.

5 Habitats

There are four major habitat types that are surveyed. These include shorelines/coastal environments, rivers and waterways, oceans (sea surface, water column and seafloor) and biota. Inland habitats, including natural, built environment and refuse collection facilities are also surveyed for litter and solid waste. As this report focuses on marine litter monitoring, we focus on the marine and aquatic rather than the inland habitats. There are four main habitats for monitoring marine litter quantity and change through time identified by GESAMP (Kershaw et al., 2019): shoreline, seawater, seafloor and biota. We expand on these categories to include aquatic waterway environments.

5.1 Shorelines and coastal environments

Coastal environments encapsulate the transition from terrestrial landscapes to the ocean. Items found in coastal environments tend to include a mix of locally deposited (lost or littered) items that have been dropped directly into the coast or have been transported from a nearby land-based source via wind or rain, litter that has arrived from nearby via local river inputs, and items that may have been transported by oceanic processes such as currents and onshore wind. Coastal environments are the most popular regions to conduct marine litter surveys because coastal environments are often appreciated for their recreational value, and it is the clear interface between land and sea. Many coastal environments include beaches of various substrates, and small islands may be considered entirely coastal with respect to marine litter. Surveys and monitoring programmes of shoreline and coastal environments may focus on the litter sitting on the substrate surface, in the intertidal zone, buried in the substrate/sediment (for example, buried in sand), or a combination of these compartments. Manual clean-ups, often including citizen scientists or volunteers, are the most popular way that coastal monitoring programmes or surveys are conducted. However, a range of other techniques also exist, such as beach-sweeping of sandy beaches and remote sensing surveys, such as those that use video footage taken by unmanned aerial vehicles or drones.

Available guidance: GESAMP Chapter 4. Monitoring methods for shorelines.

5.2 Rivers and waterways

Though not strictly a marine environment, rivers are an increasingly common habitat for anthropogenic litter survey programmes, as they reflect items that are locally deposited from the nearby human population and rarely confounded by items that arrive via oceanic transport. Monitoring of anthropogenic litter in freshwater or brackish aquatic environments has many parallels with monitoring anthropogenic litter in the marine environment, and the same monitoring principals largely apply. The quantity of litter that flows down a river is typically strongly linked to rainfall, with more litter being transported with large rainfall events, and less litter being flushed or transported when the weather is dry. River monitoring programmes, like coastal and other monitoring programmes, will optimally include the weather at the time of the survey, whether significant rainfall has occurred before the survey, and the time since the last major rainfall event. Manual clean-ups of the edges of rivers and waterways often include citizen scientists or volunteers. Other methods include the use of booms to capture litter as it is transported down the river and remote sensing, such as video recording devices placed on the underside of bridges and other infrastructure.

UNEP has recently developed guidelines for the assessment of plastic contamination, from macro- to microplastics, in freshwater environments. The report contains the most current procedures for monitoring and analysing plastic content in rivers, lakes, reservoirs, and water/wastewater treatment plants (UNEP 2020). The report builds on the large body of knowledge and experience gained from marine plastic monitoring and was developed through a project group, consisting of seven experts in different fields, co-led and funded by UNEP. The report aims to provide guidance for monitoring and assessment methods of plastic waste in freshwater, toward harmonization of monitoring protocols that enables results to be easily compared and integrated in a growing database of knowledge and understanding of plastic pollution sources, pathways and impacts.

Available guidance: United Nations Environment Programme (2020). Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonization of Methodologies. Nairobi.

5.3 Oceans (sea surface, water column and seafloor)

Oceanic surveys may encompass the sea surface, water column and/or the seafloor. Ocean plastic usually arrives from inhabited landmasses, where litter is transported to the ocean via rivers or from the coast, ultimately ending up along the coastline or in the ocean. Marine litter can also arrive in the ocean through direct deposition of litter from ships and other maritime vessels, including both intentional deposition such as dumping at sea of land-based waste and waste from ships, or accidentally through items falling off ships or fishing gear becoming lost/derelict (Derraik 2002). Marine litter in the ocean is typically much more sparsely dispersed compared to coastal and river environments but can accumulate in high densities in some regions near to the coast (Hardesty et al. unpublished), on the seafloor in submarine canyons (Peng et al. 2020; Woodall et al. 2014), as well as in subtropical oceanic gyres or along windrows. The North Pacific subtropical gyre is famously referred to as the "Great Pacific Garbage Patch" for its high density of buoyant marine litter, with an estimated 1.8 trillion items, weighing an estimated 79 thousand tonnes, floating in an area of 1.6 million km^2 (Lebreton et al., 2018). Surface trawling, such as using a manta net, is the most common method for sampling the sea surface for floating debris. Seafloor surveys often occur by manual counts, with the use of bottom trawl nets and via clean-ups of litter on the seafloor carried out by divers. Additional survey approaches include the use of dredges and core sampling of debris embedded in the sediment, and photographic and/or video footage taken by manned or unmanned underwater vehicles or robots. Sampling of the oceanic water column is the least common survey method, with very little known about marine litter throughout the water column.

Available guidance: GESAMP Chapter 5. Monitoring methods for the sea surface and water column and Chapter 6. Monitoring methods for seafloor.

5.4 Biota

Many marine and coastal species eat and become entangled in marine litter. Surveying biota can be a useful way to sample litter for environmental monitoring purposes, for wildlife conservation and animal welfare purposes. It is also an approach that is increasingly taken to understand the potential impacts to human health. Edible biota such as the blue mussel, *Mytilus edulis*, and small fish such as anchovies, *Engraulis sp.*, and sardines, *Sardina sp.* and *Sardinops sp.* are common taxa for study (Pennino et al., 2020; Renzi et al., 2019). Commercially harvested species of edible bivalves and small fish are often selected as they are abundant in the environment, commonly eaten, and single animals have a low monetary value. Stomach samples from edible species are often sub-sampled from intentional harvests for human consumption for the purpose of quantifying the amount of plastic or micro plastic contained therein. When monitoring biota that are known to interact with plastic but are threatened, such as marine mammals, sea turtles and seabirds, individuals are typically opportunistically collected. Opportunistic collection methods include those that are caught as by-catch in fisheries, and those that wash up dead on the beach.

Plastic can also be monitored in the waste products of some wild animals, for example, by collecting the scats of sea lions or the regurgitated pellets of seabirds.

Available guidance: GESAMP Chapter 7. Monitoring methods for marine biota.
United Nations Environment Programme (2020). Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonization of Methodologies. Chapter 5.6 Sampling of freshwater biota.

6 Survey design

Survey design is the key underpinning component required to develop a high-quality data set. It is useful to consider design at a number of levels, working down through a hierarchy (Hardesty et al., 2016). For quality data to be generated from a monitoring programme, whether that be coastal environments, rivers and waterways, oceans or biota, balance and representation is critical. Surveys are ideally balanced across variables that are being assessed, control for biases are incorporated into the study design and included within site replication. An ideal monitoring programme also affords the opportunity to make predictions about areas where surveys are not able to be conducted. Therefore, the sampling design must cover the range of conditions for which predictions will be made.

6.1 Balanced surveys to account for potential variables

Surveys should be balanced across any variable for which inference or conclusion is to be made. For example, for monitoring change in debris load or composition through time, surveys need to cover the time period in question. Similarly, for detecting change and variation across geographies, it is best if all locations are surveyed or monitored at similar intervals i.e., consistently. For example, if the goal is to detect temporal or geographic change across rivers, then sampling should be structured according to the river locations and representatively account for factors that could confound or bias the results, such as the number of people living near to the river. If the sampling is not balanced, for example, including variations in sampling over time or location, this can make it more difficult to interpret the findings.

6.2 Avoiding bias in site selection

For sound survey design, it is critically important to control bias in site sampling. Controlling for bias is particularly important in situations where there may be correlations between the chance of choosing a site and the variables affecting the site. For instance, access to coastal sites might be part of the survey location choice but is also likely to affect visitation rates by the public, which could also influence deposition rates for debris. It is important to use tools like randomization to avoid these biases to the extent possible, and where not possible to collect data to allow estimation of their effects in the analysis.

6.3 Within-site replication

Due to variation at sites, it is important to have within-site replication. Coastal and inland locations, in particular, vary significant in their litter loads even at small spatial scales (for example, there may be an accumulating cove at one end of the beach site, where one may record orders of magnitude

more debris or litter). Replication at the site level and stratification of replicates across the conditions at each site can assist in allowing estimation or identification of the variables that contribute to the differences that appear in litter loads, for example. Finally, controlling survey effort and observation error is a key consideration. Ideally, any item in a survey should have an equal probability of detection, irrespective of size, shape, location, and observer. This is clearly an impossible task; thus it is important to control observer effort and detection probability to the extent possible. This can be done through standardizing search area, search approach (i.e., do observers record what they observe from standing height, bend down, sift through sand, etc.) search time, and search speed.

6.4 Sampling hierarchy if predicting outside observed conditions

Finally, given the impossibility of conducting surveys under all circumstances or at all locations, ideally why we want to be able to make predictions about sites we not have not been able to survey. Hence, it is essential that the sampling hierarchy described above covers the range of conditions for which predictions will be made. Analysis of different data types requires a multitude of statistical tools. Clearly identifying the main questions or goals of the project at the outset allows for appropriate analysis and interpretation of data. For example, if one wants to identify the baseline level of litter on the coastline and the goal is to make projections outside of where litter was collected or reported at sites, it is important to stratify the sampling such that various coastal types are sampled in proportion to their occurrence. If surveys only encompass one substrate type or are of one shape, aspect, or slope, it is difficult to make predictions about the amounts of litter that may occur at other sites within the region.

7 Use of citizen science marine litter surveys

Citizen science surveys are often utilized with the intention of collecting data at minimal cost across broad geographic and temporal ranges (Dickinson et al., 2010). For marine litter, citizen science surveys have been found to be similarly robust to more formal scientific surveys and equally accurate at identifying litter types (van der Velde et al., 2017), though there has been a reported detection bias against small items (Loizidou et al., 2018). One caveat concerning the representativeness of citizen science clean-ups compared to designed surveys is that citizens typically target easily accessible, 'dirty' and accessible areas - that is, sites which are "accumulating" sites for marine litter (Hardesty et al., 2017). Targeting sites in this manner makes it difficult to extrapolate to other regions, in contrast to taking a designed-based approach (Hardesty et al., 2017). Despite these caveats, citizen science surveys provide valuable and accessible broad-scale data.

7.1 Incorporating citizen science into marine litter monitoring

Citizen scientists often provide a valuable contribution to marine litter monitoring programmes. When working with citizen scientists, it is important to ensure that those contributing their time and passion to the project are sufficiently trained in survey protocols and methodology if joining an existing programme. If initiating a new programme, we recommend that the citizen scientists are encouraged to follow the guidelines provided in this report, and to prioritize surveys of regions that are under-represented within existing marine litter monitoring programmes. We also recommend experienced and professional surveyors provide training and support to citizen scientists. This

support might come in the form of assistance designing a survey programme, provision of training videos, or even remote mentorship. This is even more important if citizen scientists are acting in coordinator or leadership positions. We recommend that citizen scientists are properly trained in the methodology before the clean-up or monitoring activity begins. For volunteer participants, this training could occur immediately prior to the beginning of the programme, especially if the group consists of one-off or 'drop-in' volunteers. For citizen scientists that will be acting in leadership/coordinator roles, or volunteers that are contributing on an ongoing basis, we recommend dedicated training sessions be conducted before the start of the activity. We further recommend that trained or professional surveyors be on-site during the initial surveys to support citizen scientists, answer questions and ensure that the methodology is being correctly followed. Ideally, even the simplest "clean-up" activity will report 1) the number of people engaging in the activity; 2) the amount of time spent by participants in the activity; and 3) the area that was surveyed or cleaned up.

Citizen science example: A local government was under pressure to conduct marine litter surveys through local wetland areas, but was suffering staffing and resource shortages, creating frustration for residents. A local "friends of the wetland" community group banded together to help the local government keep their wetlands clean, agreeing to meet once monthly for a two-hour clean-up and survey. The local government surveys were carefully designed with clear methodologies. The survey protocols were emailed to participants; however, no training was provided. Once received, the community groups diligently got to work removing litter from their local wetlands. One group cleaned the wetland but did not carefully itemize and record the collected litter, seeing careful record-keeping a waste of time that could be used to remove more litter. Another group contained a particularly enthusiastic subset of participants, who would continue to pick up litter for many hours after the two-hour survey's conclusion, diligently recording each item along-side those that were counted during the two-hour survey. Without training on survey procedures and importance of record-keeping, these well-intended deviations meant that it was no longer possible to harmonize survey data to meet broader litter-reduction and policy goals. Simply put, the two groups did not record information or carry out activities in the same way. If they had recorded the number of people at each session, the amount of time spent during the activity, and recorded the size of the area that was cleaned up, comparisons could have been made, in spite of the differences.

Available guidance: GESAMP Chapter 3.5. The role of citizen science. CSIRO methods handbook.

8 Examples of global marine litter monitoring programmes

There are hundreds if not thousands of litter monitoring programmes globally, including programmes run by governments, NGOs, universities, and community groups, occurring across multiple habitat types. Among these programmes are four large, multijurisdictional programmes, the larger of which have been adopted across more than 100 countries globally. These surveys are undertaken by a combination of citizen science surveys and professional surveys.

8.1 Ocean Conservancy International Coast Clean-up (ICC)

The Ocean Conservancy is a United States of America based Non-Government Organization (NGO) that advocates for environmental issues affecting the ocean. The Ocean Conservancy began the 'International Coastal Clean-up' programme more than 30 years ago. This volunteer-led coastal marine litter survey and clean-up programme has been run in more than 150 countries. Ocean Conservancy's ICC programme includes coastlines, rivers and waterway habitats.

8.2 PADI AWARE Dive Against Debris

PADI AWARE Dive Against Debris programme is a seafloor citizen-science marine litter survey and removal programme, launched in 2011. Since the programme's inception, Dive against Debris has been undertaken in 120 countries around the world, reporting over 1.6 million pieces of litter.

8.3 National Oceanic and Atmospheric Administration Standing Stock Surveys

The National Oceanic and Atmospheric Administration's (NOAA) monthly Marine Debris Monitoring and Assessment Project (MDMAP) is part of the United States of America's NOAA Marine Debris Program. The NOAA standing stock survey programme focuses on shorelines habitat and is applied broadly across numerous jurisdictions in the United States of America. The NOAA MDMAP serves as a template for multiple litter monitoring programmes.

8.4 CSIRO Global Plastics Leakage Project (GPLP)

The CSIRO Global Plastic Leakage Project (GPLP) applies designed field surveys and mathematical modelling to document and predict the distribution of plastic lost to the ocean from major urban centres and surrounding areas around the world. In its inception, the statistically robust, designed project focused on countries that have been identified as having significant waste mismanagement or losses into the coastal and marine environment. CSIRO's GPLP survey programme comprehensively captures data from multiple habitats, including coastlines, rivers and waterways, sea surface and inland sites. It is suitable for trained volunteers and is providing the most robust global estimate of plastic losses to the marine environment in the world, based on empirical data.

8.5 Survey design in global marine litter monitoring programmes

The four listed global marine litter monitoring programmes, Ocean Conservancy ICC, PADI AWARE Dive against Debris, NOAA standing stock surveys and CSIRO Global Plastics Leakage Project each take different approaches to survey design. Here we summarize survey design and sampling bias identified in each of these programmes.

Table 1 Survey design in multijurisdictional global marine litter monitoring programmes

SURVEY DESIGN	OCEAN CONSERVANCY INTERNATIONAL COAST CLEAN-UP (ICC)	PADI AWARE DIVE AGAINST DEBRIS	NOAA STANDING STOCK SURVEYS	CSIRO GLOBAL PLASTIC LEAKAGE PROJECT
Stratification of sites	NO	NO	NO	YES
Randomization of site location	NO	NO	NO	YES

Replication within sites	NO	NO	YES	YES
Stratification within sites	NO	NO	NO	YES
Randomization within sites	NO	NO	YES	YES
Control of survey effort	NO	NO	YES	YES
Control of detection probability	NO	NO	YES	YES

Table 1. Shows that multijurisdictional litter clean-up and survey programmes are not equivalently suitable for COBSEA RAP MALI Objective 4: Improve monitoring and assessment of marine litter and its impacts for a science-based approach.

9 Science-based best practice approaches to marine litter monitoring

From the globally accepted guidelines of the GESAMP 2019 report, and the review of literature, we have compiled five science-based, best practice suggestions for marine litter monitoring.

The five tenets for designing national and regional scale marine litter monitoring programmes (e.g., establishing baselines and monitoring changes through time):

1. Clearly delineated and repeatable methods.
2. Quantification and reporting findings in a way that is harmonized with other surveys and uses policy-relevant categories, as best possible.
3. Representative capture of variation within each habitat to avoid sampling bias.
4. Accounting for data collection effort.
5. Representation of different habitats.

9.1 Summary of survey design suggestions

Clearly delineated and repeatable methods

Repeatability and reproducibility are a challenge for all scientific disciplines and monitoring programmes. This is also challenge for marine litter monitoring, where questions such as “when” “where” and “how” can completely change how a survey is conducted and the results found, based upon the data collected. When, where and how are especially important in long-term monitoring programmes to be sure that the results found are representative and are not artefacts of a survey conducted in a different place (even small distances can affect the litter found in complex and heterogenous habitats), at a different time (monsoon vs dry season, before or after a big celebration or clean-up) or using a different search method (vehicle survey vs foot, walking vs hands-and knees, recording what is on the surface vs digging through sand). Controlling for detection probability by specifying the searching methodology is particularly important. For example, the methodology may specify searching by walking in a straight line or transect (rather than random searching) or searching while standing (rather than on hands-and-knees).

Methodology example: A local river-watch group conducts monthly clean-ups along the banks of a river, removing items from the riverbank and meticulously recording data on the types of items removed and where they are located. To make sure surveys were comparable, the same section of river was always surveyed. The clean-up is run with a rotating roster of clean-up co-coordinators, who direct staff and volunteers. After several years of clean-up, the data was analysed, and it was realized that though plastic items were consistent between months, some clean-ups had many more glass and ceramics recorded than others, and some coordinators found no glass or ceramics at all on their clean-ups. When clean-up coordinators were asked about their methods, some were instructing their participants to get on their hands and knees while searching, and to remove underwater litter that they can reach. Other clean-up coordinators did not get on their knees to search and did not pick up submerged items. To remedy the problem, all clean-up coordinators held a training to ensure that the methods were consistent, clearly delineated and repeatable in the future.

Quantification and reporting findings in a way that is harmonized with other surveys and uses policy-relevant categories

There are many different methods by which marine litter monitoring programmes quantify and report their findings. The usefulness of a study is ultimately determined by the quality of this reporting, which is based upon the data collected. The ability to 'harmonize' and to directly compare findings and glean policy-relevant information from these studies/programmes is key for designing effective and successful monitoring programmes.

Harmonization example: A popular coastal resort town runs marine litter clean-up activities each year. Several of the beach-side resorts participate in the Ocean Conservancies ICC programme and the local dive centre runs coral reef clean-ups through PADI AWARE's Dive Against Debris programme. The resorts continued to operate through the COVID-19 pandemic with mandated use of latex gloves and masks for staff and guests. After a PADI AWARE's survey, the dive centre approached the resort management to complain that the coral reef was covered in latex gloves and that they need to do something to stop their staff and guests irresponsibly disposing of gloves. The resorts suggested that gloves are not from the resort, but waste from a nearby food preparation factory flowing downstream into the reef. They further argued that no latex gloves were found on their recent ICC programme on resort beaches. However, when the data was checked to work out whether the factories or resorts were to blame for the influx of gloves, it was not possible to verify whether the number of gloves on beaches had changed since the pandemic due to a mismatch in reporting categories.

Policy-relevant categories example: A regional fisheries organization is concerned about the plastic they pull up in their fishing nets and wants to understand whether the fish they are catching and selling for human consumption are eating plastic. Looking on the internet, they found a study that examines the shapes and material of marine litter items that different fishes eat and whether these items resemble the natural prey of the fish. Interested to understand whether the fish they catch and sell eat similar items. Knowing the importance of method

harmonization, they follow the clearly delineated and repeatable methodology provided by the authors, following step-by-step to conduct an identical study. By sampling the diet contents in the stomachs of 1 in every 100 fish caught for a month, they found that most fish were eating 'linear' shaped litter items, but not ball or sheet shaped items, and that all litter items eaten by the fish were plastic.

A report was written and presented to policy makers to reduce the input of litter items that fish are likely to eat. When the policy makers read the report, they were very concerned about the public health ramifications, but did not know the source of 'linear' plastic as they did not know what the items were. Experiencing pressure to act, the policy makers approached a fishing tackle supplier about fishing line and a logistics company about rope and strapping. The tackle supplier said the linear plastic must be ropes from the logistics company as fishing line is too long for fish to eat. The logistics lobbyist said that the linear plastic must be fishing line from recreational fishers as they don't lose their ropes or strapping to the ocean. Had the fisheries organization reported the relevant level of detailed information, they could have reported that most of these 'linear' items were fibres from polyester clothing and fragmented nylon rope. This policy-relevant information could aid legislation about treatment of wastewater to reduce polyester fibres and incentivize the replacement of old frayed nylon ropes for local marine industries.

Representative capture of variation within each habitat to avoid/minimize sampling bias

Biases can be easily introduced by not representatively capturing within-habitat variation. Often sampling biases are not intentional, but small differences in the way a survey is conducted can lead to very large differences in results. Biases can be introduced by lack of randomized or representative site-selection, for example, concentrating marine monitoring on the dirtiest beach along a coastline, or even just surveying the litter-dense strandline of a beach, at the high tide mark. Therefore, the surveys are best designed in such a way that the monitoring programme representatively records data from within each habitat or sub habitat type. Randomization of survey sites and within-site replication, within each habitat is the best practice. Randomization and within-site replication are not always possible, and there are other suitable (analytical) methods available to achieve statistical robustness in analysing data from monitoring programmes.

Representation within habitat example: After complaints from residents about dirty beaches, a local council set up a marine litter monitoring programme to find the source of the issue. The municipality is bordered by a zig-zag coastline containing 10km of sandy beaches. Across one month, council officers conducted weekly surveys of the 2km stretch of sandy beach that was closest to their workplace. They chose to monitor this beach because it is easiest to get to, sheltered by the strong onshore winds affecting other beaches and has popular food stands to buy lunch after the survey. The survey concludes and the municipality found that the main debris items affecting their municipal area is the packaging of food and beverages sold by food stands along the beach and littered by beach goers. The municipality begins to implement a plan to provide additional bins and encouraged the food stands to reduce packaging of take-away food. After successful implementation, they were confused when residents continued to complain about the dirty beaches. By surveying just one beach, the council did not have the data to understand the broader litter patterns in their municipality. Beach aspect, accessibility and infrastructure affect the accumulation of different quantities or types of litter. In this council area,

the adjacent beach, facing a different direction and into onshore winds, is littered by plastic and hygiene waste transported by a major river nearby.

Account for survey / data collection effort

Variation in survey effort can mislead results and undermine an entire programme if survey effort is not controlled or accounted for.
Measures of data collection effort may include:

- The number of people that carried out the survey,
- The size of the survey area, and
- How long people spend searching (Hardesty et al., 2016).

Sampling effort need not be absolutely consistent on every survey, but it does need to be accounted for in survey design and execution, so that changes detected can be confidently distinguished as real, and not an artefact of sampling bias. By quantifying sources of survey effort, such as the number of people, area surveyed and survey duration, statistical methods can be applied to the results to reduce or account for sampling biases. Standardization methods takes this information into account to get a 'true' representation of the amount of litter at each site. This is not to say that people must spend the same amount of time conducting each survey. By simply recording the start and stop time of each survey, for example, and how big an area and how many people are searching the area, analyses can take the differences into account.

Survey effort example: After the introduction of container deposit legislation, a follow-up citizen science survey of plastic bottles in a wetland finds more plastic bottles than during the initial wetland survey. However, a survey organizer reports that more people undertook the follow-up survey than the initial survey, but the number of participants was not recorded. Did the legislation cause more plastic bottles to be deposited in the wetland, or was the outcome biased by more participants finding more bottles? Did they look harder so they could retrieve bottles and receive the financial reward? Without recording key pieces of information, it is not possible to answer these questions.

Representation of different habitats

Different types of habitats accumulate different types and quantities of litter (Roman et al., 2020). To account for the inventory of litter in the marine environment, different habitats must be sampled according to the objectives of the monitoring programme. There are four main habitats for monitoring marine litter quantity and change through time (Kershaw et al., 2019): shoreline, seawater, seafloor and biota. Different survey approaches are required for each of the different ocean compartments.

Representation of different habitats example: A local marine animal rescue and rehabilitation NGO was concerned about the amount of sea turtles that were arriving in their facility with plastic in their stomach. However, beach monitoring programmes showed that sandy beaches in the area had very little plastic on them, and therefore the government concluded that the sea turtles must be eating plastic outside of the jurisdiction. Not convinced, the NGO commissioned a marine litter survey of a major river coming out from the city, and sea surface trawls in the river's delta, revealing large loads of plastic in both. As not all beaches accumulate plastic, depending

on variables such as wind direction, the direction of currents, onshore forcing and the shape of the beach, the local authorities were underestimating the amount of plastic entering the marine environment and impacting on endangered marine species.

Part II Inventory of monitoring efforts in COBSEA countries

Part II of this report describes the marine litter monitoring and survey programmes undertaken by COBSEA participating countries.

10 What is currently being done in COBSEA countries?

To identify existing monitoring programmes and knowledge gaps, COBSEA participating countries provided information on monitoring efforts within their respective countries. As suggested by the WGML, first, these efforts were **compiled** in a monitoring inventory (see below) that has been updated and completed pending remaining country inputs and further validation. This forms the foundation of this document which serves as a regional guidance report. Second, existing programmes and efforts were **reviewed** in view of the five survey design suggestions in line with international guidance (see Part I). Finally, these tables serve to identify **successes, gaps and opportunities**; what is done well (successes), where gaps remain for further development, and the opportunities to improve and harmonize approaches. Findings were shared with countries and the WGML to provide additional input and validate compiled information to inform further discussion of joint objectives, core indicators, harmonized approaches and quality standards.

10.1 Timelines

After the initial webinar on the 7th of October 2020, an Excel spreadsheet was sent to participants during November 2020. The spreadsheet asked the participants nine questions, including a request to list the programmes, actions, activities currently taking place, the details or what is or was done, what are/were the goals of the activity, what are/were key questions addressed, what is/was the frequency of the activity and starting year, where the activity/activities took place (location), and whether there is a datasheet and communication materials.

From the survey results, we compiled the following marine litter monitoring regional guidance. The inventory was initially not exhaustive, as not all countries provided information. Through additional efforts, deeper engagement with countries and additional time has allowed countries to share their information and provide input on the initial monitoring inventory, enabling us to build this regional guidance document. Data shared by countries will not be made publicly available without country consent. The information collected will be used to meet the recommendations in RAP MALI and from WGML for identifying marine litter monitoring efforts in COBSEA countries toward regional harmonization.

Note: the information from some of the country partners was received several months after the proposed date and was integrated into the document at a later stage.

Table 2. Timeline of items and contact dates that have occurred to date.

17 OCT 2020	Webinar held on process towards preparing regional guidance on harmonization							
BY DEC 2020	Participating countries invited to provide information on existing marine litter monitoring programmes							
Marine litter programme information received, validated and integrated in the regional monitoring inventory:								
CAMBODIA	CHINA	INDONESIA	MALAYSIA	PHILIPPINES	REPUBLIC OF KOREA	SINGAPORE	THAILAND	VIET NAM
16/12/20	15/04/21	COBSEA focal point 07/04/21 & CSIRO contacts 19/02/21	17/11/20	21/02/21	22/01/21	17/12/20	17/12/20	COBSEA focal point 06/04/21 & CSIRO contacts 02/03/21
18 MAR 2021	Webinar presented draft inventory and initial recommendations for country input							
29-30 JUN 2021	3rd Meeting of the WGML reviewed and finalized Guidance and recommended for adoption							

10.2 Compiling an inventory of marine litter monitoring efforts to inform regional guidance

Ongoing monitoring programmes and efforts by COBSEA participating country were catalogued, based on information provided to CSIRO by COBSEA WGML focal points and additional monitoring contact persons and technical partners via an Excel spreadsheet. In addition to the information provided by COBSEA focal points, we also used information from PADI AWARE's DAD reports, Ocean Conservancy's ICC reports, CSIRO contacts and partners, CSIRO's GPLP website and ASEAN+3 meta-data searches of published literature on marine plastics to include additional information.

Across COBSEA member countries, 135 programmes were identified. These included a combination of one-off surveys/programmes and ongoing active marine litter monitoring programmes. Some monitoring programmes occur secondary to well-known international clean-up programmes, including the Ocean Conservancy International Coastal clean-up and PADI AWARE Dive Against Debris, which operate in most of the COBSEA participating countries. Some countries have specific marine litter monitoring programmes, either based on an international litter monitoring methodology, such as CSIRO's Global Plastics Leakage Project, or a customized monitoring effort at either a national, subnational, or local/habitat scale. The most comprehensive marine litter monitoring programme occurs in the Republic of Korea, with bimonthly monitoring at 40 sites across the country.

10.3 One-off surveys and published outputs of previous one-off activities

A comprehensive suite of one-off surveys has been conducted in COBSEA participating countries. Information from participants identified more than 100 one-off programmes and surveys, most of which are research programmes undertaken by universities. A comprehensive information list is available in Annex 1. A list of 269 publications on marine litter in ASEAN+3 countries, including meta-data of published literature on marine plastics, compiled by COBSEA and National University of Singapore in 2019 and 2020, is available online[2]. The COBSEA plastic pollution research

[2] https://cutt.ly/MLdatabase

database has been expanded and updated in 2021 and will be available in 2022 through the East Asian Seas Regional Node. Some of the programmes identified by COBSEA participating countries overlap with those programmes and resulting publications compiled for ASEAN+3, while others do not overlap.

10.3.1 Cambodia

COBSEA focal points identified 15 activities that were one-off debris surveys or survey / community engagement activities (both one-off and ongoing), including household surveys and interviews about waste management. Most programmes occur on Cambodia's islands including Koh Sdach, Koh Rong and Koh Krabey. Also included among one-off surveys is a river and waterway habitat in the Mekong River Delta. ASEAN+3 meta-data of published literature on marine plastics identified three publications on marine litter in Cambodia at the time this report was compiled, examining macroplastics on the coastline of islands and on coral reefs. However, Cambodia focal points have identified that this ASEAN+3 meta-data of published literature on marine plastics is incomplete and that several additional reports/papers have been published.

10.3.2 China

The People's Republic of China (PRC) COBSEA focal points identified five one-off marine litter programmes in PRC covering a variety of habitats. Examples include a baseline national survey of microplastics in coastal beaches, sea water, sediments and organisms and rivers flowing into the sea and monitoring programmes exploring several major rivers and estuaries.
Universities in China are dedicated in conducting and publishing marine litter research. ASEAN + 3 meta-data of published literature on marine plastics identified 129 publications on marine litter within PRC at the time this report was compiled. These studies comprised both environmental sampling studies as well as laboratory studies of plastic. Among the environmental sampling studies, several aimed to quantify macro and microplastics, and were conducted by universities. These survey and sampling efforts examined specific sites or groups of sites, with some studies containing as many as 20-50 sites. Through China, university marine litter studies cover different habitats including numerous sea surface trawl sampling studies, in addition to coastal and shoreline studies (mostly beaches), rivers and estuaries, sediment (ocean) and biota (oysters, mussels, clams, various species of fish and the Indo-Pacific humpback dolphin).

10.3.3 Indonesia

Indonesia COBSEA focal points identified seven one-off programmes within Indonesia. The programmes primarily comprised of short-term marine litter monitoring, including a microplastics study conducted Indonesian Institute of Sciences (LIPI- Lembaga Ilmu Pengetahuan Indonesia), waste data collection by Marine Research Centre and university studies published as undergraduate theses.
PEMSEA has identified the ASEANO project that they are conducting baseline research into plastic pollution within the Citarum River Basin until 2021.
Furthermore, in collaboration with CSIRO, Udayana University in Bali conducted island wide surveys along the coastline, as well as in inland and riverine habitats.
ASEAN + 3 meta-data of published literature on marine plastics identified 64 publications on marine litter in Indonesia at the time this report was compiled. These activities predominantly

comprised surveys and monitoring of a limited number of sites (most 15 or less) or whole islands, aiming to quantify macro and microplastics, and are conducted by universities. These survey and sampling efforts cover many habitats including coastal and shoreline studies (predominantly beaches), sediment (ocean and estuary), biota (bivalves, various species of fish) and sea surface trawl sampling.

10.3.4 Malaysia

COBSEA focal points identified 69 surveys and activities in Malaysia. These activities predominantly comprised surveys and monitoring of a limited number of sites (most six or less) or whole islands, aiming to quantify macro and microplastics, and were conducted by universities. These survey and sampling efforts covered many habitats including coastal and shoreline studies (beaches, wetlands, mangroves), sediment (ocean and mangrove), biota (sea cucumber, various species of fish, zooplankton) and sea surface trawl sampling. Community group clean-up and surveys of coastlines and seafloors (coral reef) also occur in Malaysia. Surveys of rivers and waterways are less well represented than other habitat types. ASEAN + 3 meta-data of published literature on marine plastics identified 36 publications on marine litter in Malaysia at the time this report was compiled, which are included in the activities identified by COBSEA focal points.

10.3.5 Philippines

COBSEA focal points and ASEAN + 3 meta-data of published literature on marine plastics identified 15 publications on marine litter in the Philippines at the time this report was compiled. These studies included coastline debris (beach), seafloor sediment surveys, a river survey and surveys of biota, both edible (various fish species, oyster, cultured green mussel) and wild (cetaceans and sea turtle).
PEMSEA has identified the 'ASEANO project' that conducts research on both the presence and composition of plastic waste within the river, and the socioeconomic impact and use of plastic by nearby residents that may interact with the waste issue.

10.3.6 Republic of Korea

ASEAN + 3 meta-data of published literature on marine plastics identified 67 publications on marine litter in the Republic of Korea at the time this report was compiled. These studies comprise both environmental sampling studies as well as laboratory studies of plastic, many conducted by various departments and institutes, in addition to universities. Korean studies typically cover large numbers of different sites (rarely less than 10, and up to hundreds) and predominantly cover coastlines and shorelines, and sea surface trawls. One biota study examines farmed bivalves. Numerous studies in ongoing research activities on plastics and micro plastics are led by OSEAN, an NGO that works closely with government and industry.

10.3.7 Singapore

ASEAN + 3 meta-data of published literature on marine plastics identified nine publications on marine litter in Singapore at the time this report was compiled. Eight of these studies were conducted by the National University of Singapore and one by citizen scientists. These studies examined macroplastics and microplastics on different types of coastlines/shorelines, including intertidal coral reef, seagrass, mangroves and sandy beaches.

10.3.8 Thailand

COBSEA focal points identified two one-off activities, one experimental study, and other of the barcodes of litter items on coastlines. ASEAN + 3 meta-data of published literature on marine plastics identified nine publications on marine litter in Thailand at the time this report was compiled. These included a combination of shoreline surveys (sandy beaches) and biota surveys (various fish species, oyster, barnacle, periwinkle, bivalves and a study of whale shark).

10.3.9 Viet Nam

The response received from Viet Nam COBSEA contacts regarding ongoing marine litter programmes in Viet Nam identified seven programmes beginning in 2020, which have been listed here (Annex 1) as one-off programmes. These include preliminary research on the state of marine plastic in some Marine Protection Areas in Vietnam that involve collection of relevant socio-economical information on the management of plastic debris in several cities and provenances.
The Institut de Recherche pour le Développement, France, provided information regarding three activities, a social survey and two surveys of waterways. The CSIRO Global Plastics Leakage Project has been conducted in Viet Nam, surveying coastlines, sea surface, rivers and inland in collaboration a Viet Nam NGO. ASEAN + 3 meta-data of published literature on marine plastics identified four publications on marine litter in Viet Nam at the time this report was compiled. Three were based on sampling activities, one of coastlines (beaches- plastic for persistent organic pollutant analysis) and two of rivers (Saigon River).

10.4 Ongoing monitoring programmes

Across the responding countries, 39 ongoing monitoring programmes were identified. Below is a table compiling the responses, and more comprehensive information is available in Annex 1.

10.4.1 Cambodia

Cambodia partakes in two current and ongoing marine monitoring programmes, a reef monitoring programme, and PADI AWARE. The reef health programmes do not have marine litter as a focus, though the coral reef surveys collect incidental data on marine debris at two sites: Koh Rong Archipelago and Koh Sdach Archipelago. Multiple reef monitoring programmes occur, listed separately in Annex 1, but these have been combined as reef health monitoring in Table 3. Of the seafloor programmes, only the PADI AWARE dive against debris programme specifically targets marine litter, whilst the other programmes focus on monitoring reef health, and marine litter data collection is incidental. A third monitoring programme for the monitoring of micro-plastic in freshwater ecosystems in the Mekong River Delta was due to start in 2019 but is currently on hold due to COVID-19.

10.4.2 China

PRC COBSEA focal points identified three ongoing monitoring programmes in the PRC, which cover a variety of habitats including rivers and waterways, shorelines and coastal environments and oceans (sea surface and seafloor). PRC conducts a comprehensive annual “China National Marine Litter and Microplastics Monitoring Project" that examines both macro marine litter and microplastics on beaches, the sea surface and seafloor across a broad range of sites along the

mainland coastline. These activities take place as part of annual national water quality monitoring, summarized in the annual “Bulletin of Marine Ecology and Environmental Status of China", at numerous sites across the coastline. PRC also undertakes a National Key Research and Development Program of China project on marine microplastic research: "Monitoring and Ecological Risk Assessment of Microplastic Marine Debris" and Coastal Marine Litter Survey and clean-up in Dalian, China.

10.4.3 Indonesia

There were five ongoing monitoring programmes identified in Indonesia. Indonesian COBSEA focal points identified one national marine litter monitoring programme, monitoring beach litter throughout 26 locations conducted by the Directorate of Coastal and Marine Pollution and Degradation Control, Ministry of Environment and Forestry, Indonesia. This four-year beach monitoring takes place from 2017-2021, occurring 1-2 times per year. PADI AWARE's dive against debris programme, conducting seafloor surveys, is also regularly undertaken in Indonesia. Ocean Conservancy's ICC programme of coastlines is carried out in Indonesia each year.

10.4.4 Malaysia

COBSEA focal points and CSIRO identified five marine litter monitoring activities occurring in Malaysia. Tropical Research and Conservation Centre in Sabah conducts island coastline clean-ups throughout the year. A newly initiated programme seeks to take stock and report on marine plastic pollution in the Coral Triangle and to provide potential strategies to minimize it. PADI AWARE's dive against debris programme conducting seafloor surveys is undertaken in Malaysia. Ocean Conservancy's ICC programme of coastlines is also undertaken annually in Malaysia.

10.4.5 Philippines

COBSEA focal points and CSIRO identified four marine litter monitoring activities occurring in the Philippines. ‘Adopt-an-estero Waterbody Program’ and ‘Manila Bay Clean-up Program’ focus on cleaning rivers and waterways, and coastal areas, however these programmes are clean-up focused primarily and survey data is not collected (sometimes mass of items, but items are not identified). PADI AWARE's dive against debris programme conducting seafloor surveys for Marine litter is undertaken in the Philippines. Ocean Conservancy's ICC programme of coastlines is undertaken in the Philippines.

10.4.6 Republic of Korea

COBSEA focal points and CSIRO identified three current marine litter monitoring activities occurring in the People's Republic of Korea (ROK). The ‘Korea National Beach Litter Monitoring Program’ occurs bi-monthly across 40 coastline sites. PADI AWARE's dive against debris programme conducting seafloor surveys is undertaken regularly in ROK. The ROK is beginning, in 2020, a new microplastic monitoring programme “Microplastic distribution status monitoring”, which will cover 40-50 sites across the country and monitor microplastic on beaches, the ocean (sea surface and seafloor) and biota (oysters). Ocean Conservancy's ICC programme of coastlines takes place annually in ROK.

10.4.7 Singapore

COBSEA focal points and CSIRO identified five marine litter monitoring activities occurring in Singapore. Singapore conducts a nationalized version of the Ocean Conservancy ICC, "International Coastal Clean-up Singapore (ICCS)", that cleans and records the data from 20,000 metres of Singapore's shoreline. PADI AWARE's dive against debris programme conducting seafloor surveys is undertaken in Singapore. In addition to these activities, there are two ongoing coastal clean-up programmes, one of beaches and one of mangroves, and a seafloor (coral reef) programme.

10.4.8 Thailand

COBSEA focal points and CSIRO identified seven marine litter monitoring activities occurring in Thailand. Thailand's marine littering programmes comprehensively assess numerous habitat types, including waterways, ocean, coastline, and biota. Thailand has a quarterly programme collecting floating debris from major rivers and lake along the Coastal in the Gulf of Thailand using the stow net. Thailand also conducts an annual beach clean-up programme. Thailand conducts a biannual microplastic in sea water and sediment sampling programme. Thailand conducts occasional but ongoing gut content analysis of dead endangered marine animals, and amount of plastics are assessed. Furthermore, there is an annual estimation of the amount of plastic marine debris, calculated from amount of waste generated by 23 coastal provinces and proportion of plastics in the total waste. PADI AWARE's dive against debris programme conducting seafloor surveys is undertaken in Thailand. Ocean Conservancy's ICC programme of coastlines is undertaken annually in Thailand.

10.4.9 Viet Nam

The response received from Viet Nam COBSEA contacts regarding ongoing marine litter programmes in Viet Nam identified seven programmes beginning in 2020, though without specifying whether these programmes will be ongoing, and as such they have been listed as one-off programmes (see 10.3.9).

The Institut de Recherche pour le Développement, France, conducts the COMPOSE project "Creating an Observatory for Measuring Plastic Occurrences in Society and Environment", and assessment of microplastic in 22 aquatic environments (predominantly rivers and waterways). PADI AWARE's dive against debris programme conducting seafloor surveys is undertaken in Viet Nam. Ocean Conservancy's ICC programme of coastlines also takes place annually in Viet Nam.

Table 3. Brief inventory of marine litter monitoring programmes in COBSEA countries. ***Note: full inventory is provided as Annex 1 of this report.***

Country	Habitat	Programmes, actions, activities currently taking place?	How often? (annually, monthly, weekly, daily)? For how long?	How big an area? Local, city, watershed, state/territory, entire country?
	Cambodia n= 3			
Cambodia	Oceans (Seafloor)	Reef Health Monitoring (incidental data collection re: marine debris) - Cambodian Coral Reef	Annually	National / coastwide - members include: Marine Conservation Cambodia (NGO);Wild Earth Allies (NGO); Centre for Biodiversity Conservation

		Monitoring Network (CCRMN)		(CBC) & the Royal University of Phnom Penh (RUPP); Private sector diver shops, including Kuda Divers and the Khmer Dive Group; Liger Leadership Academy (student-led marine research team); Song Saa Foundation (NGO / Foundation); MaFREDI (Federal Marine Research institute); Royal University of Agriculture (RUA); Fisheries Administration (part of the Ministry of Agriculture, Forestry and Fisheries (MAFF)); FFI.
Cambodia	Oceans (Seafloor)	PADI AWARE Dive Against Debris	Commonly throughout year	Various locations, though most are concentrated at Koh Sdach, Koh Rong and Koh Kong
Cambodia	Rivers and waterways	Monitoring of micro-plastic in freshwater ecosystems in the Mekong River Delta	On hold	Mekong River Delta. Was due to begin 2019 and currently on hold due to COVID.
		Peoples Republic of China n=3		
China	Shorelines and coastal environments, Oceans (Sea surface and seafloor)	China National Marine Litter and Microplastics Monitoring Project	Marine litter since 2007, Microplastics since 2016	Coastal zone and coastal waters of China's coastal areas
China	Rivers and waterways, Shorelines and coastal environments, Oceans (Sea surface)	National Key Research and Development Program of China project on marine microplastic research: "Monitoring and Ecological Risk Assessment of Microplastic Marine Debris"	2016	Typical estuary (Yangtze River estuary, Pearl River estuary), offshore (Bohai Sea, Yellow Sea, East China Sea)
China		Coastal Marine Litter Survey and clean-up in Dalian, China	2003	There are about 30 sites in the coastal area of Dalian city.
		Indonesia n= 5		
Indonesia	Shorelines and coastal environments, Rivers and	CSIRO / NOAA methodology survey on the river,	Monthly and six-monthly	Unknown

	waterways, Oceans (Sea surface)	shoreline, inland, and offshore		
Indonesia	Shorelines and coastal environments	Marine Litter Monitoring (Directorate of Coastal and Marine Pollution and Degradation Control, MoEF Indonesia).	Annually or biannually	26 locations in Indonesia (National)
Indonesia	Rivers and waterways, Oceans (Sea surface), Biota	Identification of microplastic on the seawater, biota, and lake	Annually	Provincial/regency
Indonesia	Shorelines and coastal environments	Ocean Conservancy ICC	Annually	Varied
Indonesia	Oceans (Seafloor)	PADI AWARE Dive Against Debris	No regular time frame / 16 events organized	Varied
	Malaysia n= 5			
Malaysia	Shorelines and coastal environments	Tropical Research and Conservation Centre in Sabah	Throughout year	Pom Pom Island and Kalapuan Island Sabah
Malaysia		Stocktake report on marine plastic pollution in the Coral Triangle and to provide potential strategies to minimize it	*This programme is just beginning but planned to be a continuous effort*	Multijurisdictional effort including Malaysia, Indonesia, Papua New Guinea, Philippines, Solomon Islands and Timor-Leste
Malaysia	Other	Detection of microplastics in human colectomy specimens	Continuous effort from 2019	Selected colorectal patients in Malaysia
Malaysia	Oceans (Seafloor)	PADI AWARE Dive Against Debris	Many throughout year	Various locations but concentrated in key coral reefs, including Mabul Island, Tioman Island and Semporna
Malaysia	Shorelines and coastal environments	Ocean Conservancy ICC	Annually	Various locations across Malaysia
	Philippines n= 4			
Philippines	Rivers and waterways	Adopt-an-estero Waterbody Program	Unknown	Entire country
Philippines	Shorelines and coastal environments, Rivers and waterways	Manila Bay Clean-up Program	Unknown	The Manila Bay area covers eight (8) provinces and 178 local government units in three regions of the country, namely: National Capital

				Region (NCR), Region III, and Region IV-A. Of the eight provinces, four are coastal (Bataan, Bulacan, Cavite and Pampanga); four are non-coastal (Laguna, Nueva Ecija, Rizal and Tarlac).
Philippines	Shorelines and coastal environments	Ocean Conservancy ICC	Annually	Unknown
Philippines	Oceans (Seafloor)	PADI AWARE Dive Against Debris	Regular throughout year	Many locations throughout Philippines
	Republic of Korea n= 4			
Republic of Korea	Shorelines and coastal environments	Korea National Beach Litter Monitoring Program	Bimonthly for 13 years	100 m length of coastline at 40 sites nationwide. Please see the guideline attached Start at 20 sites and increase to 40 sites from late September 2014
Republic of Korea	Shorelines and coastal environments	Ocean Conservancy ICC	Annually	Clean-ups conducted at many sites by Our Sea of East Asia Network (OSEAN) and KOEM
Republic of Korea	Oceans (Seafloor)	PADI AWARE Dive Against Debris	No regular time frame	Various locations. Many conducted at Chilpo Beach
Republic of Korea	Shorelines and coastal environments , Oceans (Sea surface and seafloor)	Microplastic distribution status Monitoring	Twice annually for beach and seawater. Annually for seafloor and biota (oyster).	Entire country: 40 sites for beach, 50 sites for seawater, sea bottom, and biota
	Singapore n= 5			
Singapore	Shorelines and coastal environments	International Coastal clean-up Singapore (ICCS)	Annually, 60 - 90 minutes duration, 70-90 organizations, ~3,500 volunteers	Entire country
Singapore	Oceans (Seafloor)	Our Singapore Reefs (OSR)	5 -6 times a year, 2 dives (60 mins each) per sessions. 20 - 30 volunteers each time.	Southern Islands
Singapore	Oceans (Seafloor)	PADI AWARE Dive Against Debris	Occasionally	Pulau Hantu and Lazarusisland
Singapore	Shorelines and coastal environments	Coastal clean-ups in mangrove environments by Little Green Men Singapore	Typically, monthly unless delayed by unpredictable events like haze or COVID-19. Each clean-up takes place over 2 hours, including briefing, set up, clean-up, debrief, and at times	Mangrove sites, usually along a 50 metre stretch in Singapore. Site varies from clean-up to clean-up, but has been regular in 2019 (Sungei Seletar) and 2020 (Sungei Buloh Wetland Reserve).

			a brief tour of the site.	
Singapore	Shorelines and coastal environments	Cleaning of selected beaches	Beaches under NEA purview are cleaned through the year with frequencies ranging from four times a week to once in two weeks depending on the public usage and accessibility of the beach. The cleaning frequency is increased twice a day for selected beaches during monsoon periods as more marine litter are washed ashore.	Selected beaches covering small sections of the coastline.
	Thailand n=7			
Thailand	Shorelines and coastal environments	Monitoring on Marine Debris in the Gulf of Thailand generated from Major Waterways	Quarterly	Along the coastal area of the Gulf of Thailand
Thailand	Ocean (water column and seafloor)	Monitoring on Microplastic in sea water column and sediment in the Gulf of Thailand and Andaman Sea	Biannually	Along the coastal area of the Gulf of Thailand and Andaman Sea
Thailand		Amount of marine debris	Annually	The Gulf of Thailand and Andaman Sea
Thailand	Shorelines and coastal environments	Beach Clean-Up	Annually	Along the coastal area of the Gulf of Thailand and Andaman Sea
Thailand	Biota	Plastic Debris in Endangered Marine Animals	Occasionally	Along the coastal area of the Gulf of Thailand and Andaman Sea
Thailand	Oceans (Seafloor)	PADI AWARE Dive Against Debris	Commonly throughout year	Various locations with many occurring at Ao Nang
Thailand	Shorelines and coastal environments	Ocean Conservancy ICC	Annually	Various locations
	*Viet Nam n= 3**			
Viet Nam	Oceans (Seafloor)	PADI AWARE Dive Against Debris	Commonly throughout year	Various locations though mostly occurring at Nha Trang and secondarily, Duong Dong
Viet Nam	Shorelines and coastal environments	Ocean Conservancy ICC	Annually	A few locations around Viet Nam

Viet Nam	Rivers and waterways	COMPOSE project Creating an Observatory for Measuring Plastic Occurrences in Society and Environment	Every 3 months	Twenty-two locations around Viet Nam
Viet Nam		TBC	TBC	TBC

10.5 Summarizing existing monitoring activities

Across COBSEA member countries, there are many active marine litter monitoring programmes. Some monitoring programmes occur secondary to well-known international clean-up programmes, including the Ocean Conservancy International Coastal clean-up and PADI AWARE Dive Against Debris, which operate in most of the COBSEA participating countries. Some countries have specific marine litter monitoring programmes, either based on an international litter monitoring methodology, such as CSIRO's Global Plastics Leakage Project, or a customized monitoring effort at either a national or local/habitat scale. The most comprehensive marine litter monitoring programme occurs in the Republic of Korea, with bimonthly monitoring at 40 sites across the country.

10.5.1 Ocean Conservancy's International Coastal Clean-up (ICC) programme

There are active Ocean Conservancy's ICC activities occurring across the nine COBSEA participating countries (though to a lesser degree in Cambodia). In all countries, part or all of ICC clean-up activity is conducted in a non-representative method (locations are selected by participants rather than pre-selected for representativeness) by a combination of individuals, community, and corporate groups and organizations. In some countries, larger dedicated organizations, especially environmental NGOs, for example, 'Marine Conservation Philippines' in the Philippines and 'Our Sea of East Asia Network' (OSEAN) in the Republic of Korea, perform more delineated and representative ICC clean-ups of the same coastline annually. In Singapore, the ICC has been adopted into a national model, 'International Coastal Clean-up Singapore', that covers sites across most of Singapore's coastline.

10.5.2 PADI AWARE's Dive Against Debris (DAD) Programme

PADI AWARE's Dive Against Debris programme operates in most COBSEA countries including Cambodia, Indonesia, Malaysia, Philippines, Republic of Korea, Singapore, Thailand and Vietnam. Some countries have very regular seafloor clean-ups occurring, predominantly occurring on coral reefs near towns with a tourism-strong economy.

10.5.3 CSIRO's Global Plastics Leakage Project (GPLP)

Baseline surveys for the CSIRO GPLP have occurred across several COBSEA partner countries, though are less wide-spread and have not been conducted in an ongoing manner after initial baseline surveys. Viet Nam and the Republic of Korea have completed two surveys and Indonesia and China have each completed one survey. There are future surveys anticipated within Malaysia, Philippines, Singapore and Thailand.

10.5.4 National-scale Litter Monitoring Programmes

The Republic of Korea, the People's Republic of China and Singapore have the most well-developed national-scale marine litter monitoring programmes of the surveyed COBSEA partner countries. The 'Korea National Beach Litter Monitoring Program' occurs bi-monthly across 40 sites. The People's Republic of China conducts a comprehensive annual 'China National Marine Litter and Microplastics Monitoring Project', conducted alongside other water quality monitoring programmes at hundreds to thousands of sits across the country's coastal and estuarine regions. In Singapore, the Ocean Conservancy ICC has organized into a national ground-up marine debris monitoring programme, 'International Coastal Clean-up Singapore (ICCS)', that cleans and records the data from 20,000 metres along Singapore's shoreline.

Thailand conducts a number of national monitoring programmes across varied habitats; coastal, sediment, sea surface and biota. The Philippines has two national clean-up programmes, 'Adopt An Estero' and the 'Manila Bay Clean-up Program', which aim to remove litter from the waterways but do not include a monitoring component. National-scale monitoring programmes are under-represented in other COBSEA participating countries.

10.5.5 Local or Habitat-scale Litter Monitoring Programmes

Local and habitat-scale monitoring programmes are common among COBSEA countries, with a multitude of programmes tackling marine litter in a multitude of habitats, often with little synchrony between locales. A majority of the 99 one-off survey programmes constitute local or habitat-scale monitoring. Some habitats are popular for ongoing monitoring efforts, particularly coral reefs.

10.6 Reviewing ongoing monitoring activities in COBSEA countries

Here we review the ongoing monitoring efforts and programmes in each country, as far as provided, along the five tenets for designing national and regional scale marine litter monitoring programmes discussed in Part I.

10.6.1 Clearly delineated and repeatable methods

Most of the monitoring programmes have delineated and repeatable methods, though some do not, especially programmes where the focus is cleaning up litter rather than surveying. Some COBSEA participating countries have very thorough instructions available online, such as the 'Korea National Beach Litter Monitoring Program' while others are at earlier stages of delineating and designing their national programmes.

10.6.2 Quantification and reporting findings in a way that is harmonized with other surveys and uses policy-relevant categories, as best as possible.

The major monitoring programmes conducted across multiple countries (OC's ICC, PA's DAD and CSIRO's GPLP) report their findings by quantifying specific items, though some clean-up and monitoring programmes report by mass of removed debris. The quantification categories are compatible between surveys for most items across OC's ICC, PA's DAD and CSIRO's GPLP, and compatible with the other national monitoring programmes, such as the 'Korea National Beach Litter Monitoring Program'. Reporting mass of items removed is less frequently recorded. Such efforts, unless paired with item counts, do not distinguish between a wet or dry mass of litter items.

Mass alone is seldom a valuable reporting metric for designing policy, as it does not provide important information on the composition of litter, and because different items have different masses, mass is not informative with regard to the accounts of particular items. For example, one large, discarded metal item, such as a vehicle part or household appliance, may weigh as much as thousands of plastic bags, or hundreds of thousands of plastic fragments. This is an important point to consider with respect to survey design and data collection.

10.6.3 Representative capture of variation within each habitat to avoid sampling bias.

The representative capture of variation within each habitat is mixed. The Republic of Korea, People's Republic of China and Singapore's national monitoring programmes achieve this goal in shorelines and coastal environments, as do the countries that have conducted baseline surveys using the CSIRO's GPLP.

In the two most monitored habitats, shorelines and seafloor, other monitoring programmes do not capture variation within habitats. Shoreline habitat surveys are biased towards the monitoring of level, easily accessible sandy beaches and the monitoring of coral reefs typically takes place in seafloor habitats.

The most widespread programmes, OC's ICC and PA's DAD, are designed as clean-ups and community engagement events, with monitoring as an auxiliary objective. Consequently, these programmes do not explicitly account for randomization of site location, replication within sites, stratification within sites and randomization within sites (see Table 1). However, some administering organization of these programmes, such as Our Sea of East Asia Network (OSEAN) in the Republic of Korea, have scheduled OC IPP activities geographically in such a way to provide representative capture of variation within each habitat.

10.6.4 Accounting for data collection effort.

Most of the surveys record survey effort, such as the number of participants, the distance or area cleaned and the duration of the clean-up/survey (duration being the least reported metric), however few specifically control for survey effort. The most widespread clean-up methods, OC's ICC and PA's DAD, are designed as clean-ups and encourage community participation as their primary goals, in addition to litter removal, and monitoring is secondary. Consequently, they do not inherently account control for survey effort and detection probability (see Table 1).

10.6.5 Representation of different habitats

Shorelines and coastal environments are well represented across the participating countries ongoing monitoring programmes, and to a lesser extent, seafloors through PA's DAD programme, though with lower representation outside of coastal coral reefs. Oceanic near-shore environments, both the sea surface and seafloor, are well-represented in the People's Republic of China's National monitoring programme. Rivers and waterways are represented well in programmes that include CSIRO's GPLP, and in some OC ICC clean-ups. In addition to coastal and coral reef monitoring, sea surface, sediment and biota monitoring programmes are conducted in Thailand, which has the most representative habitat sampling programme of COBSEA participating countries. Overall, sea surface and biota sampling are under-represented across COBSEA participating countries.

10.7 Successes, gaps, and opportunities in COBSEA monitoring activities

10.7.1 Successes

It is promising that all nine countries are already conducting monitoring activities of one variety or another. Two specific clean-up programmes provide a source of secondary monitoring across two different habitats. Ocean Conservancy's ICC programme of coastal/shoreline habitats and PADI AWARE's DAD programme of seafloor habitats, are well established across most participating countries, providing an opportunity for harmonizable monitoring. Several countries, exemplified by the Republic of Korea, have high quality marine litter monitoring programmes already established, providing a template of success that others may choose to follow. Likewise, CSIRO's GPLP programme has been conducted across several COBSEA partner countries and is planned in others, providing an alternative template that meets the five tenets for designing national and regional scale marine litter monitoring programmes, and has additional ancillary benefits associated with its robust design. The data output of Ocean Conservancy's ICC, PADI AWARE's DAD, the Republic of Korea's National Beach Litter Monitoring Program and CSIRO's GPLP can be harmonized across data categories, providing the opportunity for transboundary monitoring programmes.

10.7.2 Gaps

In most participating countries, there is a gap for representative capture of variation within each habitat to avoid sampling bias, and representation of different habitats. For example, most coastal/shoreline monitoring of different countries in biased in favour of sandy beach monitoring, and seafloor surveys are biased in favour of coral reef monitoring. These leave other habitats, such as rocky, pebbled, slab, or muddy coastlines, and mangroves and rocky seafloors unrepresented. Across jurisdictions there is a gap in monitoring rivers and waterways, ocean (sea surface and water column) and biota (with some exceptions, for example PRC, Thailand and Indonesia), though the initiation of new monitoring programmes, such as microplastic monitoring in ROK, will fill some of these gaps. Malaysia's monitoring programme included a microplastic and human-health monitoring programme, which is unique among programmes.

10.7.3 Opportunities

Two widespread monitoring activities, Ocean Conservancy's ICC and PADI AWARE's DAD, can be guided in such a way that can provide useful monitoring information by including stratification, randomization and replication to the programme. There are examples within two COBSEA participating countries where this has been effectively implemented, providing a template for success. To better sample under-represented habitats using a method that meets the five tenets for designing national and regional scale marine litter monitoring programmes, we recommend expansion of survey programmes that are already established in the region, for example 'Korea National Beach Litter Monitoring Program' the CSIRO GPLP programme.

Part III Recommendations for harmonizing marine litter monitoring

In part III of this report, we provide recommendations for harmonization of national monitoring programmes based on the regional marine litter monitoring inventory and country input.

11 General recommendations for COBSEA participating countries

11.1 Recommendations overview

It is important to acknowledge there are a number of actions and activities taking place within the region, with many opportunities for countries to engage with both COBSEA and ASEAN regional frameworks and global processes. Regional guidance provides targeted recommendations based on country input, existing efforts in the region, and regional priorities recognizing global guidance and international processes to enable peer learning and avoid duplication. A core focus in developing this guidance has been to ensure there is no replication of efforts and there is a strong focus on harmonization of approaches and ensuring consistency (and expansion) of information and guidance.

We recommend COBSEA countries benefit from opportunities already provided by existing programmes. By leveraging the successes of existent programmes and bridging the gaps, harmonization of COBSEA monitoring programmes can be achieved through making small changes to existing efforts, following examples already implemented by some countries. Overarchingly, we recommendation to improve attention to reporting of survey efforts across all monitoring programmes and, where possible and appropriate, align data sheet reporting categories for comparability within and between regions. Two clean-up activities that are already widespread, Ocean Conservancy's ICC and PADI AWARE's DAD, can be adapted in such a way that each can provide useful monitoring information by including stratification, randomization, and replication to the programme. To better sample underrepresented habitats using a method that meets the five tenets for designing national and regional scale marine litter monitoring programmes, we recommend the adoption and expansion of survey programmes that are already established in the region, for example the CSIRO GPLP programme. Introduction of monitoring of currently under-represented compartments, including biota, is also recommended.

11.2 Attention to timing of surveys

One question that is often front of mind is the consideration of when to conduct surveys or monitoring efforts. International or National Clean Up days may be when surveys are initially conducted, though given the seasonality and differences in rainfall throughout the year within the region, knowing when to monitor becomes important. We know that after a big rainfall event such as occurs at the beginning of the monsoon season, a large 'flush' for flux of litter flowing along rivers or watercourses is often seen on its pathway to the sea. If there is capacity to survey a single time during the year, and a goal is to compare changes annually, it is important to survey each year during the same time window. If there is capacity to conduct multiple surveys throughout the year, we would suggest surveys pre- monsoon or rainy season and after the 'first flush' of major rains (consider this an opportunity for a BACI approach). If it is possible to survey 3-4 times per year, we would encourage spacing those surveys in time, so they occur regularly throughout the year – approximately every 3-4 months. If it is possible to survey monthly, we would encourage surveying at a similar time of the month for the duration of the monitoring period. What is achievable and what is optimal in terms of frequency of survey occurrence depends upon the key questions one is trying to answer, in alignment with the resources and capacity available.

11.3 Attention to surveys that include litter that may enter waterways and move to the coastal/marine environment

There is increasing acknowledgement and understanding of the role of waterways in the transport of litter from land to sea (Lebreton et al. 2018; Meijer et al. 2019). With that, we see a rising interest in identifying monitoring approaches that support a better understanding of how waste flows across freshwater (riverine) systems to the coastal and marine environment. We recommend a monitoring approach that encompasses a whole-of-watershed approach to survey design and monitoring, by including surveys across the available land types within a watershed, surveys along watercourses (rivers/creeks/streams) within the watershed, and coastal and nearshore surface surveys as well. The use of stratified random design, whilst accounting for site accessibility, and using multiple transects at each site, enables a robust, yet rapid approach to survey the landscape to understand how waste flows across habitat types to the sea. This is the approach that has been developed by CSIRO. It has been implemented and undertaken in multiple watersheds/cities/countries within the COBSEA region (and beyond). By aligning with this approach, countries are able to compare their results with other countries within the region, as well as within the broader global context.

11.4 Attention to reporting survey effort across monitoring programmes

We recommend attention to reporting of survey effort across all monitoring programmes. Many of the one-off and ongoing programmes already include at least one measure of survey effort, however these effort mechanisms are not consistent nor are results always standardized with attention to differing survey effort, leading to different results (see 9.1).

We recommend that each survey/monitoring programme, at a minimum, report:

1. The area (m^2 or km^2) surveyed and length of the survey (m or km) if following a boundary such as river or shoreline.
2. The number of surveyors
3. The duration of the survey, reporting start and end time.

The inclusion of just these three measures of effort across surveys will greatly aid multijurisdictional harmonization efforts.

11.5 Attention to aligning the data reporting categories of national monitoring programmes

There are numerous, high-quality national-scale monitoring programmes already being conducted in COBSEA participating countries, including the Republic of Korea, the People's Republic of China and Singapore. However, the data reporting categories differ slightly between these, compromising comparability of data. We recommend aligning reporting categories so that they are consistent with agreed lists of categories, such as the EU-MSFD (Directive, 2013) (Guidance on Monitoring of Marine Litter in European Seas (europa.eu)). If it is not feasible to broadly harmonize survey reporting categories, we recommend include/harmonizing at least across key policy-relevant items to allow direct regional comparisons across key common and policy-relevant items. Examples might include the top 10 most common items, identified globally, in the Ocean Conservancy and PADI AWARE clean-ups.

The 10 most common litter items, presented in rankings on land and seafloor respectively, were cigarettes (1st and 15th), plastic fragments (2nd and 3rd), fishing line (20th and 1st), plastic beverage bottles (4th and 5th), food wrappers (3rd and 7th), metal cans (8th and 4th), glass bottles (10th and 6th), plastic bottlecaps (5th and 14th), plastic bags (7th and 9th) and synthetic foam (6th and 17th) (Roman et al. 2020). However, including more categories is useful, as trends may change in space and time. CSIRO's approach utilizes categories similar to the ICC and DAD methods, specifically for harmonization.

Available guidance: GESAMP Chapter 2.4. Types of plastic marine litter and 3.3.2. Marine litter categories.

CSIRO's handbook of Survey Methodology (2018). CSIRO, Australia. ePublish EP178700

The Marine Strategy Framework Directive (MSFD). Guidance on Monitoring of Marine Litter in European Seas

United Nations Environment Programme (2020). Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonization of Methodologies. Chapter 8.1 Categories of plastics in freshwater.

11.6 Adoption and expansion of programmes already operating in the region that fulfil the five tenets for designing national and regional scale marine litter monitoring programmes

Adoption of and expanding on national studies that that fulfil the five tenets for designing national and regional scale marine litter monitoring programmes, and have already been conducted regionally, provides a valuable starting point to guide future monitoring efforts. There are two examples of ongoing and one-off baseline monitoring programmes operating within COBSEA participating countries that we recommend as suitable for adoption and expansion into ongoing monitoring programmes (for example, annual or biannual programmes) in other jurisdictions. First, for coastal habitat monitoring, the Republic of Korea's "Korea National Beach Litter Monitoring Program" exemplified the five tenets for designing national and regional scale marine litter monitoring programmes. This approach would serve as a valuable template for monitoring programmes in other COBSEA participating countries. Second, CSIRO's Global Plastics Leakage Project monitors debris across several habit styles and baselines have been established already for China, Republic of Korea, Viet Nam and Indonesia, with future collaboration and data collection exercises anticipated in Cambodia, Malaysia, Philippines, Singapore and Thailand.

11.6.1 Republic of Korea's "Korea National Beach Litter Monitoring Program" (Coastlines only)

The Republic of Korea's "Korea National Beach Litter Monitoring Program" is a quality national marine litter monitoring programme that could be adopted in other jurisdictions. Meeting the five tenets for designing national and regional scale marine litter monitoring programmes, this well-designed coastal litter monitoring programme could serve as a template of bi-monthly monitoring for COBSEA participating countries.

11.6.2 CSIRO's Global Plastics Leakage Project (Inland, Coastlines, Rivers and waterways, Ocean- Sea surface)

Expanding on national baseline studies that have already been conducted provide valuable starting points for the expansion and adoption of national monitoring programmes. The CSIRO's Global Plastics Leakage Project is designed to survey several habitats: coastlines, inland areas, rivers and waterways and ocean (sea surface), with surveys already undertaken across numerous countries globally, including several of the COBSEA participating countries, as well as in other countries in Africa, the Americas and beyond. Meeting the five tenets for designing national and regional scale marine litter monitoring programmes and having already been conducted as a baseline survey across multiple COBSEA participating countries, expansion of the CSIRO GPLP survey programme offers a quality survey programme to expand across the region for national marine litter monitoring. Importantly, it allows countries insight into how waste flows from land to the sea, incorporating watershed level surveys across different land use types as well as surveys along watercourses to better understand how water influences litter lost to the environment and where such litter arrives at the ocean.

11.7 Programmes that fulfil the five tenets for designing national and regional scale marine litter monitoring programmes in biota

Biota are under-represented in surveys throughout COBSEA participating countries, with only Thailand and Indonesia conducting an ongoing programme of monitoring plastic in endangered marine animals, though the Republic of Korea plans to initiate an annual oyster microplastic monitoring programme. Among one-off surveys, biota monitoring is popular and universities across several COBSEA participating countries have conducted surveys of both edible biota and wildlife. We recommend the expansion of ongoing marine litter-biota monitoring programmes, to address particular questions that countries may have, such as the question of food security and impacts on human health from edible biota.

11.7.1 Edible biota

There are several surveys conducted that sample edible biota in COBSEA participating countries. Microplastics surveys of invertebrates include a fMRIG-FSSM-Universiti Malaysia Terengganu survey, sampling wild and farmed sea cucumber (*Holothuria scrabra*) for ingested microplastics, and cultured edible bivalves have been surveyed in Bacoor Bay, Cavite, Philippines. For surveys of fish, several universities within Malaysia including the Universiti Sains Malaysia and Universiti Putra Malaysia, conducted surveys of microplastics in the gastrointestinal tracts of multiple fish species, destined for human consumption, purchased from markets. A collaborative study between Universiti Putra Malaysia; Monash University Malaysia and HORIBA Jobin Yvon S.A.S. investigated microplastics in the gastrointestinal tracts of in 20 brands of canned sardines and sprats across 13 countries. These and comparable surveys of edible biota can be instituted as part of national marine litter monitoring programmes. We recommend that edible biota monitoring follows five tenets for designing national and regional scale marine litter monitoring programmes. For example, by sampling the complete gastrointestinal tracts of multiple species across multiple jurisdictions and recording data in a similar manner, comparison can be made among taxa and/or regions.

Purchase of edible biota directly from fisherman and suppliers that source their catch in different seas or waterbodies affords a minimally resource intensive sampling opportunity.

11.7.2 Wildlife

Opportunistic wildlife sampling can occur through beach-patrol efforts that are likely to come across moribund or deceased wildlife as a normal part of their patrolling activities, as well as through collaboration with wildlife rescue organizations. Marine wildlife conservation, rescue and rehabilitation NGOs operate in multiple COBSEA participating countries, and partnerships with such organizations, such as by the institution of a wildlife – marine litter interaction database or 'strandings database', can collate the efforts of multiple disparate groups. Examples among one-off surveys in COBSEA participating countries include a survey to assess impacts of plastic debris on marine turtle found in Davao Gulf in the Philippines, and the 'Juara Turtle Project' in Malaysia, which conducts opportunistic sampling of stranded green turtles (*Chelonia mydas*), dissection and analysis of gut contents.

We recommend that such strandings databases or programmes follow the five tenets for designing national and regional scale marine litter monitoring programmes. If standings databases are instituted, is important to include records of all wildlife stranding, if possible, including survey effort (for example, in the case of a beach patrol scheme, the distance and regularity of patrols), and records of strandings that are not associated with marine litter. It is valuable to look at other ongoing wildlife stranding databases to ensure the best interoperability possible. Collating data related to strandings provides information that can help to accurately determine the magnitude of the threat that marine litter poses to wildlife, rather than simply recording positive or marine-litter-interaction-only records. However, there is a vast and rapidly growing literature on the impacts of marine debris on coastal and marine fauna, so the demonstration of harm has already been shown across regions, taxa, and impact types. Hence, this may not be of highest priority for establishment of national and/or regional monitoring programmes.

Available guidance: GESAMP Chapter 7. Monitoring methods for marine biota.
United Nations Environment Programme (2020). Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonization of Methodologies. Chapter 5.6 Sampling of freshwater biota.

12 Specific recommendations for programmes currently conducted across multiple COBSEA participating countries

Two clean-up activities are already widespread in COBSEA participating countries, with a data history that reaches back for many years, and an easy-to-understand template that has been designed with community participation, outreach and environmental stewardship as key objectives. The Ocean Conservancy's ICC and PADI AWARE's DAD programmes can be adapted in such a way that can provide useful monitoring information by including stratification, randomization, and replication to the programme making these few simple adjustments and improvements to coastal clean-ups, data can be collected in a more robust and representative way and inform national monitoring efforts. But beyond contribution to data collection, these clean-ups also have high value for awareness raising and community engagement and aspects of practicality and choosing simple 'user friendly' approaches should be considered when organizing such efforts. Here we make some specific recommendations to build on the efforts already undertaken to leverage these programmes for effective monitoring of local anthropogenic litter. Note that CSIRO's approach builds on these simple citizens science activities, with an increased level of robustness and analytical capability.

12.1 Representative survey design recommendations for implementation of Ocean Conservancies 'International Coastal Clean-up' programme (Coastlines)

Given that the Ocean Conservancy's ICC programme is conducted in all participating countries, we recognize and opportunity to expand upon already existing programmes. Following the example of Singapore's 'International Coastal Clean-up Singapore (ICCS)' and OSEAN's administration of OC ICC in Republic of Korea, we recommend the adoption of a stratified national programme of Ocean Conservancies 'International Coastal Clean-up'. This could be administered by a reliable NGO, as is currently administered by OSEAN in the Republic of Korea, or by government. When designing a national survey programme, the programme is most effective when it accounts for randomization of site location, replication within sites, stratification within sites, randomization within sites, and improve control for survey effort and detection probability.

Simple adjustment example for representative sites: Are there sites within your local area or region that you'd like to monitor annually that are not well represented? For example, perhaps there are many events hosted on sandy beaches, but you would like to better understand and monitor all coastal habitat types, including mangroves? Work together with local ICC representatives, local government or community groups to pre-plan a selection of sites that represent different habitats to conduct, host or aid with an annual ICC event. Perhaps clean-ups at less popular sites can be incentivised, for example, by organising hot food or cold drinks for participants or engaging local community leaders. Pre-selecting key areas that meet broader monitoring goals and supporting the organisations that host clean-ups (or hosting them through your own organisation) can benefit community awareness of anthropogenic litter and foster stewardship while meeting monitoring goals.

This approach of pre-selecting ICC sites for annual monitoring is exemplified by the national ground-up marine debris monitoring programme in Singapore, 'International Coastal Clean-up Singapore (ICCS)', an idea template that could be expanded on in other COBSEA participating countries.

12.1.1 Recommendation to improve randomization of site locations in OC's ICC

Most OC ICC programmes are conducted on sandy beaches near populated regions/city centres. To improve randomization of the site location, we recommend to "suggest sites" or that a pre-selection of sites is nominated by the local organizations responsible for OC ICC clean-ups. By nominating or pre-selecting sites before the clean-up date, representation of different types of sites (sandy beaches, rocky beaches, mangroves, riverbanks, will river deltas and other site types), nearby and distant from populated areas, can be selected to support more representative monitoring outcomes using OC ICC data.

12.1.2 Recommendation to improve replication within sites in OC's ICC

To improve replication within sites, we recommend a 'suggest site' or preselection (as above in "Recommendation to improve randomization of site location in OC's ICC"), for replication within site types. This suggestion is made in addition to subdividing large site surveys into multiple smaller surveys. For these situations, where appropriate, we recommend undertaking multiple surveys with clear start and end points within the larger area, rather than one very large survey with tens to hundreds of participants. A minimum of three surveys at a larger site is ideal.

12.1.3 Recommendation to improve stratification within sites and randomization within sites in OC's ICC

Most sites are not homogenous. For example, even a coastline that is mostly sandy beach might include a beach entrance section, a section near a car park, a modification such as a seawall, a section that is rocky or vegetated. It could also include a waterway outlet such as a drain or natural waterway, the coastline might be curved face different directions and/or experience different prevailing winds. To improve stratification and randomization within sites, especially large sites, we recommend dividing sites into smaller areas that each contain these different features. For example, a 6km coastline might contain 4km of wide sandy beach, half of which is more remote from the access point, a 1km seawall and 1km of vegetation. In a site of this variety, we recommend (if resources are available) a minimum of three surveys in advance of the clean-up activities; one for the sandy beach section, one that occurs by the seawall, and the third in the vegetated section. By stratifying and randomizing clean-ups within-sites, the survey data captures the type of within-site variation in marine litter that may occur due to the types of terrain and onshore forcing, for better information about local marine litter situations.

12.1.4 Recommendation to improve control for survey effort and detection probability in OC's ICC

The OC ICC programme attracts a variety of individuals who might survey in different ways; some will walk briskly, perhaps chatting with friends, some may diligently search on hands and knees, looking under rocks and vegetation, and everything in between. Hence, within the clean-up area,

search effort may not be constant. At a beach site, people may be more likely to walk along the wet sand or strandline, than to venture into dunes or coastal vegetation. At a river site, people may be more inclined to search at the top of the bank. Multiple participants may search along the same stretch within the survey site while all neglect another part of the survey area. We recommend that prior to surveys being conducted, the team agrees on a search methodology and divides participants' effort so that their search is evenly spread along the site, avoiding multiple teams of surveyors on some stretches while no teams survey others. This ensures consistent survey effort within the entire study area.

12.2 Representative survey design recommendations for implementation of PADI AWARE's Dive Against Debris programme (Ocean - seafloor)

PADI AWARE's Dive Against Debris programme is conducted in most participating countries, though dives are primarily targeted towards popular coral reefs near heavily touristed locations. We recommend expansion of existing PA DAD programmes through collaboration with diving clubs and organizations to increase monitoring of seafloor debris, particularly in locations that are further offshore. When designing a national survey programme, the programme is most effective when it accounts for randomization of site location, replication within sites, stratification within sites, randomization within sites, and improve control for survey effort and detection probability.

12.2.1 Recommendation to improve randomization of site location in PA's DAD

Most PA DAD activities are conducted on coral reefs and popular dive sites near to tourist regions. To improve randomization of the site location, we recommend a "suggest sites" or pre-selection of sites through a collaboration with government or NGO organizations, PADI AWARE coordinators and the dive organizations that host DAD programmes. By nominating or pre-selecting sites before the clean-up date, representation of different types of sites (sandy seafloors, rocky seafloors, muddy seafloors), nearby and distant from populated areas, can be selected to support more representative seafloor monitoring habitat types.

12.2.2 Recommendation to improve replication within sites in PA's DAD

Overall, replication within surveyed coral reef and dive sites is very good in most locations where seafloor clean-up activities take place. However, there is currently a lack of site representation and within-site representation outside of popular coral reef dive sites. To improve replication within sites, we recommend a 'suggest site' or preselection (as above in "Recommendation to improve randomization of site location in PA's DAD"), for replication within site types, in addition to subdividing large survey areas into multiple smaller surveys, depending on the number of available divers. For these situations, where appropriate, we recommend undertaking multiple surveys with clear start and end points within the larger survey area, rather than conducting a single large survey with many participants. A minimum of three surveys at a larger site is ideal.

12.2.3 Recommendation to improve stratification within sites and randomization within sites in PA's DAD

Most dive sites are not homogenous. For example, even a broader dive site may contain seafloor of different depths, different surfaces (rock, coral, mud, sand), different organisms (sponges, corals, algae/seaweeds, kelp gardens, seagrass). To improve stratification and randomization within sites,

especially large sites, we recommend dividing sites into areas that contain different features. For example, a coral reef dive site may contain a mixture of coral structures spread across sand. In such a site, clean-ups could be split into coral seafloor clean-ups and sandy seafloor surveys/clean-ups. By stratifying and randomizing data collection associated with clean-ups within-sites, the survey data could capture the type of within-site variation that may occur due to the types of terrain and forcing, such as ocean currents, for better information about local marine litter types and densities.

12.2.4 Recommendation to improve control for survey effort and detection probability in PA's DAD

Due to the nature of scuba diving, survey effort and detection probability is more even than in many land-based surveys, and underwater activities depend heavily on dive conditions such as visibility and the strength of currents, which affect divers equally during a single dive. Nonetheless, some divers will search more diligently than others, some divers are more capable than others, and may have increased skill in looking under rocks and in vegetation, while others might opt for visually searching while swimming at a distance above the seafloor. It is also possible, with pairs of divers, that some areas within the dive site are searched by multiple people while others are missed, leading to uneven search effort and detection probability. We recommend that prior to surveys being conducted, the team agrees on a search methodology and divides participants' effort so that their search is evenly spread throughout the site, avoiding multiple teams of surveyors on some areas while no teams survey others.

Simple adjustment example for survey effort: Interested in using local or national community clean-up surveys, such as Ocean Conservancy's ICC or PADI AWARE's DAD as part of a monitoring programme but are not sure whether the local programme hosts control for survey effort or detection probability? How about supporting the event organisers in hosting annual "training" event or programme in the days to weeks before the event? By inviting experienced people or professionals to share their knowledge, survey techniques can be standardized by those that host and deliver programmes, so that the results of each survey/clean-up can be reliably compared between sites and over time.

References

Borrelle, S. B., Ringma, J., Law, K. L., Monnahan, C. C., Lebreton, L., McGivern, A., . . . Rochman, C. M. (2020). Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution. *Science, 369*(6510), 1515-1518. doi:10.1126/science.aba3656

Conner, M. M., Saunders, W. C., Bouwes, N., & Jordan, C. (2015). Evaluating impacts using a BACI design, ratios, and a Bayesian approach with a focus on restoration. *Environmental Monitoring and Assessment, 188*(10), 555-555. doi:10.1007/s10661-016-5526-6.

Derraik, J. G. (2002). The pollution of the marine environment by plastic debris: A review. *Marine Pollution Bulletin*, *44*, 842–852. https ://doi.org/10.1016/S0025-326X(02)00220-5

Escalle, L., Muller, B., Brouwer, S., Pilling, G.,Dickinson, J. L., Zuckerberg, B., & Bonter, D. N. (2010) Citizen science as an ecological research tool: Challenges and benefits. In*: Vol. 41. Annual Review of Ecology, Evolution, and Systematics* (pp. 149-172).

Directive, S. F. (2013). Guidance on monitoring of marine litter in European seas. *Luxembourg: Publications Office of the European Union, doi, 10*, 99475.

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). Rep. Stud. GESAMP No. 99, 130p.

Hardesty, B. D., Wilcox, C., Schuyler, Q., Lawson, T., & Opie, K. (2016). *Developing a baseline estimate of amounts, types, sources and distribution of coastal litter – an analysis of US marine debris data. A final report for Ocean Conservancy and the National Oceanic and Atmospheric Administration of the United States*. Retrieved from

Hardesty, B. D., Wilcox, C., Schuyler, Q., Lawson, T., & Opie, K. (2017). *Developing a baseline estimate of amounts, types, sources and distribution of coastal litter – an analysis of US marine debris data. Version 1.2.* Retrieved from

Kershaw, P., Turra, A., & Galgani, F. (2019). Guidelines for the Monitoring and Assessment of Plastic Litter in the Ocean-GESAMP Reports and Studies No. 99. *GESAMP Reports and Studies*.

Lebreton, L., & Andrady, A. (2019). Future scenarios of global plastic waste generation and disposal. *Palgrave Communications, 5*(1). doi:10.1057/s41599-018-0212-7

Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., . . . Reisser, J. (2018). Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. *Scientific Reports, 8*(1), 4666. doi:10.1038/s41598-018-22939-w

Meijer, L. J. J., van Emmerik, T., Lebreton, L., Schmidt, C., & van der Ent, R. (2019). Over 1000 rivers accountable for 80% of global riverine plastic emissions into the ocean.

Loizidou, X. I., Loizides, M. I., & Orthodoxou, D. L. (2018). Persistent marine litter: small plastics and cigarette butts remain on beaches after organized beach clean-ups. *Environmental Monitoring and Assessment, 190*(7). doi:10.1007/s10661-018-6798-9.

Peng G, Bellerby R, Zhang F, Sun X, Li D. (2020). The ocean's ultimate trashcan: Hadal trenches as major depositories for plastic pollution. Water research. 2020 Jan 1;168:115121.

Pennino, M. G., Bachiller, E., Lloret-Lloret, E., Albo-Puigserver, M., Esteban, A., Jadaud, A., . . . Coll, M. (2020). Ingestion of microplastics and occurrence of parasite association in Mediterranean anchovy and sardine. *Marine Pollution Bulletin, 158*, 111399.

Plan, N. P. A. (2020). Report on Implementation of the NOWPAP Regional Action Plan on Marine Litter (RAP MALI) in 2018-2019.

Renzi, M., Specchiulli, A., Blašković, A., Manzo, C., Mancinelli, G., & Cilenti, L. (2019). Marine litter in stomach content of small pelagic fishes from the Adriatic Sea: sardines (Sardina pilchardus) and anchovies (Engraulis encrasicolus). *Environmental Science and Pollution Research, 26*(3), 2771-2781.

Roman, L., Hardesty, B. D., Hindell, M. A., & Wilcox, C. (2019). A quantitative analysis linking seabird mortality and marine debris ingestion. *Scientific Reports, 9*(1). doi:10.1038/s41598-018-36585-9

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*, 114663.

United Nations Environment Programme (2020). Monitoring Plastics in Rivers and Lakes: Guidelines for the Harmonization of Methodologies. Nairobi.

van der Velde, T., Milton, D. A., Lawson, T. J., Wilcox, C., Lansdell, M., Davis, 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. doi:10.1016/j.biocon.2016.05.025

Wilcox, C., Hardesty, B. D., & Law, K. L. (2020). Abundance of Floating Plastic Particles Is Increasing in the Western North Atlantic Ocean. *Environmental Science & Technology, 54*(2), 790-796. doi:10.1021/acs.est.9b04812

Wilcox, C., Puckridge, M., Schuyler, Q. A., Townsend, K., & Hardesty, B. D. (2018). A quantitative analysis linking sea turtle mortality and plastic debris ingestion. *Scientific Reports, 8*(1). doi:10.1038/s41598-018-30038-z.

Woodall LC, Sanchez-Vidal A, Canals M, Paterson GL, Coppock R, Sleight V, Calafat A, Rogers AD, Narayanaswamy BE, Thompson RC. (2014). The deep sea is a major sink for microplastic debris. Royal Society open science. Dec 17;1(4):140317.

Wright, S. L., & Kelly, F. J. (2017). Plastic and Human Health: A Micro Issue? *Environmental Science & Technology, 51*(12), 6634-6647. doi:10.1021/acs.est.7b00423

The Coordinating Body on the Seas of East Asia is dedicated to protecting the coastal and marine environment of the East Asian Seas for a sustainable future for all.

Contact us
United Nations Environment Programme
UN Building,
Rajdamnern Nok Av.,
Bangkok 10200, Thailand

www.cobsea.org | unep-cobsea@un.org

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.
CSIRO. Unlocking a better future for everyone.

Contact us
1300 363 400
+61 3 9545 2176
csiroenquiries@csiro.au

For further information
CSIRO Oceans and Atmosphere
Britta Denise Hardesty
+61 3 6232 5276
Denise.hardesty@csiro.au
https://research.csiro.au/marinedebris/

Annex 1. COBSEA regional monitoring inventory sheet

The regional monitoring inventory is available in spreadsheet format on the COBSEA website.