Project information	
Project full title	EuroSea: Improving and Integrating European Ocean Observing and Forecasting Systems for Sustainable use of the Oceans
Project acronym	EuroSea
Grant agreement number	862626
Project start date and duration	1 November 2019, 50 months
Project website	https://www.eurosea.eu

Deliverable information	
Deliverable number	D1.5
Deliverable title	**Marine Plastics EOV and common sampling protocol**
Description	This deliverable describes the process of establishing global coordination for sustained observations of marine plastics litter as a new type of Essential Ocean Variable (EOV) addressing the aspect of observing human impacts on the ocean. The document reports on the EuroSea efforts to implement a community vision for an Integrated Marine Debris Observing System (IMDOS) as a new element of the Global Ocean Observing System (GOOS). First version of the Marine Plastics Litter EOV Specification Sheet is included. Progress towards establishing common sampling protocols for marine plastic litter in Europe and beyond are described.
Work Package number	WP1
Work Package title	Governance and coordination of ocean observing and forecasting systems
Lead beneficiary	Institute of Oceanology Polish Academy of Sciences (IO PAN)
Lead authors	Artur Palacz
Contributors	Maciej Telszewski, Toste Tanhua, Emma Heslop
Due date	31.01.2022
Submission date	30.04.2022
Comments	The submission of this deliverable was delayed by 3 months as the process of establishing new partnerships and facilitating dialogue between many international actors responsible for setting requirements and coordinating global marine plastics observations required more time than anticipated and resulted in delays in reaching consensus on developing Marine Plastics as a new Essential Ocean Variable.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 862626.

https://doi.org/10.3289/eurosea_d1.5

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Executive summary

This deliverable report describes the process of establishing global coordination for sustained observations of marine plastics debris as a new type of Essential Ocean Variable (EOV) which is the first in a new class of EOVs which help the Global Ocean Observing System (GOOS) address the need to monitor human impacts on the ocean as mandated by the GOOS 2030 Strategy. In this document we report on the EuroSea efforts to implement a community vision for an Integrated Marine Debris Observing System (IMDOS) as a new element of the GOOS, following EuroSea's Action Plan for establishing global coordination of marine plastics debris observations which was published as a milestone report in the beginning stages of the project.

Major accomplishments in implementing the Action Plan are reported, with emphasis on the development of long-term partnerships and collaborations between several international organizations, institutions, expert working groups and other key stakeholder groups responsible for or interested in advancing marine debris monitoring including but not limited to: GOOS, UNEP Global Partnership on Marine Litter (GPML), Group on Earth Observations (GEO) Blue Planet, SCOR Working Group FLOTSAM, MSFD Technical Group on Marine Litter, GESAMP Working Group 40, UNESCO-IOC Working Group on Ocean Best Practices System (OBPS), the Ministry of Environmental Government of Japan (MOEJ), JAMSTEC, or the International Ocean Colour Coordinating Group (IOCCG) Task Force on Remote Sensing of Marine Litter and Debris.

The report presents Marine Plastics Debris as a new emerging EOV and includes the first version of the EOV Specification Sheet prepared based on current international expert guidelines and recommendations for global scale monitoring of marine plastics and other debris. Furthermore, the report summarizes the progress towards establishing common sampling protocols for marine plastic debris in Europe and beyond, in particular sampling protocols and shared survey designs which would augment existing ocean observing approaches and thereby also increase the readiness level of marine debris monitoring.

1. Introduction

1.1. The need for global coordination of marine plastic debris observations

Anthropogenic marine debris, particularly plastic, poses a growing threat to marine ecosystems, maritime activities and the well-being of the ocean users. Pollution from marine debris in the ocean is a multi-dimensional problem with economic, environmental, cultural, and, through contamination of marine food sources, human health risks and costs.

The need for global monitoring and reporting has been recognized by the United Nations (UN) by setting Sustainable Development Goal (SDG) target 14.1 on marine pollution, informed by a specific indicator on marine litter (14.1.1b) under the custody of the UN Environment Program (UNEP). However, the development of marine litter indicators and assessments is limited by lack of standardized monitoring approaches. Moreover, a global governance scheme for marine debris data collection, management and dissemination remains to be established, and should take place in coordination with UNEP and many other stakeholders. There is a demand from environmental managers, parties (states), institutions and initiatives (G7, UNEA, G20) for monitoring of marine litter/debris. Through regional Action plans, such monitoring has already been initiated to various degrees. At the same time, in 2019 the United Nations Environment

Assembly (UNEA) asked for a coordination group and a technical platform dedicated to marine litter as a global challenge.

The Global Ocean Observing System (GOOS) 2030 Strategy calls for *'a truly global ocean observing system that delivers the essential information needed for our sustainable development, safety, wellbeing and prosperity.'* Among the 11 Strategic Objectives identified by GOOS, there is the need to extend systematic observations to understand the human impacts on the ocean, including that from plastic pollution.

The OceanObs'19 Conference Breakout Session on Marine Debris, which discussed a plan for advancing a harmonized approach to marine debris monitoring, resulted in the following recommendations included in the OceanObs'19 Living Action Plan:

- A comprehensive global observing & information system is necessary to evaluate sources/sinks, abundance, trends, risks and the efficiency of reduction measures and finally to get the problem under control.
- To achieve fundamental understanding of the issues of marine debris, develop efficient in situ observation technology, remote sensors, models and monitoring strategies, involving citizen scientists when possible.
- Build an integrated, standardized and harmonized collaborative network, using commonly accepted methods & definitions, whose structure (variables, coverage, and products) answers fundamental scientific questions and societal demands.

In response to a clearly articulated need for an Integrated Marine Debris Observing System (IMDOS), as envisioned in the OceanObs'19 Community White Paper by Maximenko et al. (2019), the EuroSea project has committed to offering its capacity and resources to support the establishment of a global coordination of IMDOS in partnership with the leading international organizations, institutions, expert working groups and other stakeholder groups in Europe and globally.

The design of IMDOS as a backbone observing system needs to ensure collection and delivery of adequate, FAIR (Wilkinson et al., 2016) and open data and information which could then be integrated and synthesized into indicators and decision-support tools via relevant data centres and knowledge platforms, in line with the GPML Digital Platform Strategy (UNEP, 2020) and the Framework for Ocean Observing (FOO; Lindstrom et al., 2012).

Key to the implementation of the FOO principles is the concept of Essential Ocean Variables (EOVs). While current EOVs are specific to physics, biogeochemistry, biology and ecosystems, GOOS has been responding to the community's needs to expand the framework onto measurable indicators of human pressures, and cultural and economic aspects of the ocean.

EuroSea's Task 1.1.3 was motivated precisely by this need to establish a new type of human pressure EOV and associated coordination and observing capacity which would address the challenge of globally coordinated and harmonized monitoring of marine plastics and other debris. The process of developing this framework and capacity is described in this report.

1.2. What does it mean to be an EOV?

The process of selecting and developing EOVs as first proposed by GOOS (Lindstrom et al., 2012) turned out not to be a trivial task as it aims to cover all societal benefit areas from climate to operational services to ocean health, and all ocean disciplines from physics to biogeochemistry to biology and ecosystems. The so-

called impact vs feasibility matrix is fundamental to the GOOS EOV concept as it helps reconcile what is most needed with what is most feasible in terms of sustained ocean observations, with strong emphasis on the word sustained. The EOVs help provide pragmatic guidance for the ocean observing system design recognizing that "we cannot measure everything regularly, nor do we need to."

The impact assessment considers how a given variable addresses climate, operational services and/or ocean health, both from a scientific perspective (i.e. addressing critical knowledge gaps) and from a service perspective (i.e. addressing critical user needs for applications). Feasibility assessments considers whether the measurement is technically, politically and economically feasible to collect or otherwise estimate on a global scale using proven, scientifically understood and ethical methods. Periodic re-assessments are key to recognize changes in feasibility (innovation in the system) but also in impact reflecting ever-evolving user requirements.

Integrating requirements across all the disciplines and societal benefit areas requires a pragmatic approach which cannot always be consistent. As a consequence of this pragmatic approach, the Physics and Climate Panel of Experts of GOOS developed EOVs closely matching those variables considered as Essential Climate Variables (ECVs). The Biogeochemistry Panel of Experts of GOOS also adopted relevant ECVs but had significantly broadened the impact vs feasibility assessment exercise to arrive at a consensus list of biogeochemical variables spanning all three application areas. The Biology & Ecosystems Panel of Experts of GOOS adopted the Drivers, Pressures, State, Impact and Response (DPSIR) framework combined with the Impact and Feasibility assessment to recommend the last group of EOVs, to especially better reflect the ocean health requirements for sustained ocean observations on a global scale (Miloslavich et al., 2017).

As the FOO was meant to respond to evolving requirements and innovation in the ocean observing, new EOVs were added to the original list from 2012 such as the Ocean Surface Heat Flux EOV and the Ocean Colour EOV, and most recently the Ocean Sound EOV. The latter two presented a particular challenge as they considered observing requirements across more than one discipline and their development took place in close collaboration with relevant international programmes and projects.

Prior to being officially approved by the GOOS Steering Committee, a newly proposed EOV must first receive the status of an "emerging EOV" which recognizes the fact that:

- such an observed variable or group of variables was judged by one of the Expert Panels of GOOS to be of high enough impact and feasibility to be considered for sustained global observations
- there is an active community of experts and practitioners involved in establishing requirements for such proposed EOV observations, with potential for providing coordination and oversight for requirement setting, coordinated observing capacity, and data and information product management.

It is important to clarify that there is more to the EOVs than just the top-level list of their names. Each EOV Specification Sheet contains information on specific observing requirements for a group of parameters, called EOV sub-variables. Setting requirements for these sub-variables is akin to setting requirements for products in the Essential Climate Variable framework, and often times, is also equivalent to setting requirements for indicators - especially in the biology & ecosystem domain.

What makes EOVs unique from other EV frameworks, is the closely associated concept of setting observing requirements through phenomena which are observed processes, events, or properties, with characteristic spatial and time scale(s), measured or derived from one or a combination of EOVs, and needed to address at

least one of the science or policy needs. Each EOV Specification Sheet lists phenomena of relevance to that given EOV, spanning across ocean disciplines, along with observing requirements for a particular EOV.

Establishing any observing quantity as an EOV places a demand for global coordination of activities, adequate sampling strategies and EOV-based implementation plan which then guide the process of evolution across the entire scale of readiness levels, from concept to mature, spanning all three areas identified by the Framework for Ocean Observing: (i) requirement setting processes, (ii) coordination of observations, and (iii) data and information management.

Moreover, setting EOV requirements should not be set up in isolation from other global requirement setting frameworks wherever relevant for a given set of observations, be it EV-based (ECVs, EBVs) or indicator-based (e.g. SDG or CBD). This requires building partnerships and collaborations with the organizations who are custodians of these indicators.

Without such coordinated efforts, GOOS cannot guide the community towards the goal of increasing the readiness level of the system in terms of that EOV, and in terms of an integrated and multi-purpose observing system.

2. Marine Plastics Debris as an Essential Ocean Variable of GOOS

The above introduction on the EOV concept serves to explain that establishing community consensus and capacity for coordinated oversight of the three elements of the FOO is a necessary pre-requisite for successfully developing any new EOV. In case of Marine Plastics Debris EOV - which spans all ocean domains, this meant bringing together various existing groups, organizations and institutions who collectively provide authoritative guidance on the long-term development of this first of the human pressure EOVs.

Therefore, the majority of Section 2 of this report is in fact devoted to documenting the process of building such coordination capacity through gradual implementation of the IMDOS vision. Section 2.5 concludes with a presentation of the current initial version of the Marine Plastics Debris EOV Specification Sheet - an overview document which aims to communicate the requirements and current status of observing and data management capacity of a given EOV.

2.1. EuroSea Action Plan for an Integrated Marine Debris Observing System (IMDOS)

In October 2020, a EuroSea milestone report MS5 was submitted with the goal of presenting an “Action Plan to Establish Global Coordination of the Integrated Marine Debris Observing System (IMDOS).” The document, referred henceforth to as the Action Plan, was developed as means of mapping and fulfilling the aims of EuroSea Task 1.1.3 on developing capacity and coordination for sustained ocean observations of marine plastic contaminants, but also as means of ensuring EuroSea’s legacy in this domain.

The Action Plan identified specific actions to enable implementation of ideas and recommendations from Maximenko et al. (2019), and placed a strong emphasis on the development of the new Marine Plastics Debris EOV, and the need to establish a dedicated coordinating body with adequate Terms of Reference. The document which was consulted with several expert working groups and organizations was deemed to be in concert with plans and activities of closely related international initiatives led by UNEP, IOC-UNESCO, the EU, SCOR, GEO Blue Planet, or others contributing to the mission of the Global Partnership on Marine Litter (GPML).

The Action Plan has subsequently become a living document having already undergone further revisions following a number of dedicated meetings and workshops organized or co-organized by EuroSea (see details below), and has benefited from a stakeholder engagement strategy developed through a series of EuroSea virtual workshops on stakeholder engagement, with participation from representatives from all EuroSea work packages.

While the Action Plan does not replace the need for a Strategy and Implementation Plan required for IMDOS development, it does offer a strong basis for developing such plans. Furthermore, it identified several activities pursued by EuroSea until now which have contributed to the de facto implementation of the IMDOS vision, with several examples highlighted below.

The design of IMDOS as a backbone observing system needs to ensure delivery of adequate data and information which could then be integrated and synthesized into indicators and decision-support tools via relevant data centres and knowledge platforms, and therefore aims to complement the ongoing development of the GPML Digital Platform[1].

Successful coordination of marine debris monitoring requires a complex approach that considers the entire life cycle of artificial debris in the marine environment. Currently, this Action Plan identifies actions which would focus on the backbone of such an observing system, to provide reliable information on the state of marine pollution due to artificial debris deposited into the marine environment, and to some extent, on its impacts on marine life. This backbone would not necessarily be able to answer all the questions which motivate maintaining a marine debris monitoring system, in particular those related to monitoring land-based sources of marine litter, or the dispersion and accumulation pathways.

Establishing a globally coordinated IMDOS would fill the need for a coordinating body providing authoritative guidance on how to develop and evolve a global sustained observing system providing adequate data and information on marine debris in response to diverse stakeholder needs. IMDOS would thus occupy an important niche in a very complex and full landscape of organizations and initiatives involved in tackling the problem of marine litter pollution. Last but not least, IMDOS would provide the authoritative guidance to oversee the coordination of the new Marine Plastics Debris EOV observations, and its evolution in response to changing stakeholder requirements and technological innovation.

A peer-reviewed paper on IMDOS was published in the inaugural supplement on ocean observing in Oceanography, an official magazine of The Oceanography Society, as a direct contribution of the EuroSea project (Maximenko, Palacz, et al., 2021). It follows through from the original community white paper by Maximenko et al. (2019) but recognizes the significant involvement of GOOS in the process, enabled by EuroSea's activities.

2.2. Collaborative actions and partnership building

The overarching objective of EuroSea Task 1.1.3 was to establish global coordination of sustained observations of marine debris as a human pressure EOV by bringing together technical experts leading individual global observing networks with leading authorities focused on marine plastic pollution, and initiatives involved in monitoring, sensor development, and ecosystem impact assessments in marine debris.

[1] https://digital.gpmarinelitter.org/

To this end, throughout the 2020-2022 period IOPAN on behalf of EuroSea managed to initiate a number of close collaborations for the benefit of establishing global coordination of a future IMDOS, most notably among GOOS, UNEP GPML, the Ministry of Environmental Government of Japan (MOEJ), JAMSTEC, GEO Blue Planet, SCOR Working Group FLOTSAM, and the recently formed International Ocean Colour Coordinating Group (IOCCG) Task Force on Remote Sensing of Marine Litter and members of individual institutions presented in international expert working groups. The process benefited from the start from regular consultations with Co-Chairs of MSFD TGML on the EU level, and Co-Chairs of GESAMP WG40 on the global level.

Below is a summary of key public events which were co-organized by EuroSea, and events to which EuroSea contributed with expertise and strategic guidance; as well as contribution to initiatives which supported partnership building for the benefit of IMDOS. Unfortunately, due to the extended travel restrictions caused by the COVID-19 pandemic, many initially planned meetings and workshops were cancelled or postponed and eventually organized in a virtual format which was not always optimal to accomplish building new collaborations in the most efficient manner.

Convening the Marine Litter Working Group of the "Evolving and Sustaining Ocean Best Practices System Workshop IV"

The first EuroSea-organized event that brought together the different expert groups, international organizations and interested citizens was through convening a dedicated Marine Litter Working Group during the IV Annual Workshop of the Ocean Best Practices System (OBPS). Full scope, programme and proceedings from this community event can be found online[2].

The goal of the OBPS Marine Litter Working Group was to foster community discussions on aspects of developing guidelines and best practices for coordinated collection, quality control, streaming and management of marine litter data. The need for standardized monitoring and research on marine litter underpins the development of globally coordinated observing and information systems which IMDOS envisioned to promote (Maximenko et al., 2019). In line with the objectives of EuroSea Task 1.1.3 and the overall goals of the OBPS workshop, we have set the following objectives for the Marine Litter WG:

- Identify criteria for selecting variables and methods for which we require guidelines, best practices and standard protocols as a priority
- Establish a process towards developing first standard protocols for high impact and feasibility elements of marine debris monitoring
- Decide on the scope of best practice documentations/resources needed beyond standard monitoring, i.e. for (i) remote sensing observations, (ii) modelling, and (iii) citizen science components of marine debris monitoring
- Identify short-term actions to implement a Global Platform for Monitoring Marine Litter and Informing Action and IMDOS as its backbone

[2] https://www.oceanbestpractices.org/workshops/workshop-iv-2020/

To this end, the Marine Litter WG gathered 14 world-leading experts[3] to lead seven thematic sessions focused on best practices in a number of aspects related to marine litter monitoring, from environmental monitoring and remote sensing to modelling, citizen science, data management and knowledge co-creation. These sessions were divided as below, and recordings from most of them are available from the OBPS YouTube playlist[4].

Session #1: Global frameworks for selecting priority indicators and variables for monitoring
Session #2: Towards standard sampling protocols
Session #3: Towards best practices for remote sensing of marine debris
Session #4: Best practices for citizen science monitoring
Session #5: Best practices for modelling
Session #6-7: Global Platform for Monitoring Marine Litter and Informing Action

The Marine Litter WG was co-led by members of the EuroSea consortium: Artur Palacz (International Ocean Carbon Coordination Project/ Institute of Oceanology of the Polish Academy of Sciences, Poland), and René Garello (IEEE Oceanic Engineering Society, France) with further support from two early-career ocean professionals: Ngozi Oguguah (Nigerian Institute for Oceanography and Marine Research, Nigeria) and Florence Jovinary Peter (Institute of Marine Sciences, Tanzania).

Each session of the Marine Litter WG resulted in a concrete set of recommendations for the community and the OBPS, spanning all thematic areas mentioned above. A complete report from the WG is available as Annex 2 to the workshop proceedings[5].

In this report, we highlight the recommendations from two of the sessions which were most relevant to the results presented in this deliverable report. Recommendations from Session 1 are presented in Section 2.4 of this report, and recommendations from Session 2 are presented in Section 3.1 of this report.

UN Ocean Decade Clean Ocean Laboratory Satellite Event on IMDOS

In November 2021, the IMDOS community represented by 14 organizations worldwide held a virtual event titled 'One Integrated Marine Debris Observing System for a Clean Ocean.' Hosted by GEO Blue Planet and Mercator Ocean International, the event was intrinsically aligned with the UN Decade of Ocean Science for Sustainable Development and UN Sustainable Development Goal 14 "Life below water", and as such recognized as an official satellite activity of the UN Ocean Decade Laboratory on 'A Clean Ocean'. EuroSea co-organized this event in line with its task to develop capacity and coordination for sustained global ocean observations of marine litter.

197 participants from 46 countries attended the event which consisted of a series of three live online sessions in English and French. 26 speakers and panellists from 18 different countries world-wide came together to share their knowledge and discuss the growing threat and multidimensional problem of marine debris to

[3] Sanae Chiba (JAMSTEC, Japan), Jillian Campbell (CBD, Canada), Heidi Savelli-Soderberg (UNEP, Kenya), Francois Galgani (Ifremer, France), Alexander Turra (Univ São Paulo, Brazil), Yannick Lerat (SeaCleaners, France), Anne Bowser (Wilson Center, USA), Shungudzemwoyo Garaba (Univ Oldenburg, Germany), Paolo Corradi (ESA, the Netherlands), Christophe Maes (LOP-IRD, France), Audrey Hasson (LOCEAN-IPSL, France), Thierry Huck (LOP-IUEM), Hans-Peter Plag (Old Dominion Univ, USA), Dan Martin (Old Dominion Univ, USA).
[4] https://www.youtube.com/playlist?list=PLkuDz7rC6Mb9p-xIXqmJ8iKfVoazIa5Tr
[5] https://repository.oceanbestpractices.org/handle/11329/1540

marine ecosystems, ocean and coastal users. Participants discussed the current state of marine debris observations, recent advancements in observational techniques and technologies, and ways forward for implementing IMDOS benefiting from multidisciplinary approaches represented by diverse stakeholders. The event also included a virtual poster hall featuring 50 posters, including seven video presentations on transdisciplinary approaches, monitoring technologies and modelling, networks and digital ecosystem contributing to global marine debris observations. Session recordings and detailed information can be found on the event webpage[6].

The event resulted in several key recommendations for the future evolution of the IMDOS concept, including a recommended submission of a UN Decade Programme bid in response to the fact that up to then, there was no such proposal submitted related to the topic of marine litter pollution. More importantly however, the backstage process of organizing this event generated significant momentum among many groups and organizations willing to support the implementation of the IMDOS vision, effectively leading to establishing an initial coordinating body to replace the ad hoc networking performed up until the end of 2021.

2.3. Establishing global coordination of IMDOS

IMDOS interim Steering Committee and initial Terms of Reference

In early 2022, as a direct follow-up of the discussions about the future of IMDOS at the UN Ocean Decade Satellite Event, an Interim Steering Committee of IMDOS was created at the joint suggestion of GOOS and GEO Blue Planet. This interim coordinating body, consisting of a small group of marine litter experts and programme representatives is tasked with developing the initial version of IMDOS Terms of Reference, developing a strategy and implementation plan for IMDOS, and helping raise funds to establish a dedicated coordination office for IMDOS. Currently, partial coordination support for IMDOS is provided through EuroSea for Artur Palacz (IOCCP/IOPAN, Poland) and through EU4OceanObs for Audrey Hasson (GEO Blue Planet/Mercator International, France).

UN Ocean Conference Side Event on IMDOS

A joint GOOS, GEO Blue Planet and UNEP GPML event on IMDOS is being organized with a pending application to hold the meeting as an official side event to the UN Ocean Conference taking place on June 27-July 1, 2022 in Lisbon, Portugal. The event is co-organized and co-sponsored by EU4oceanObs and EuroSea project among other.

Building on the previous community workshops and online meetings spanning from the OceanObs'19 Conference in September 2019 to the UN Decade "Clean Ocean" Satellite activity in November 2021, this in-person event will focus on addressing the need for monitoring marine litter and plastic pollution to inform action. The event will be an opportunity to publicly present the Interim Steering Committee of IMDOS and the proposed Terms of Reference. A large group of stakeholders is planned to be invited to this non-technical event which will aim to:

- Advocate the necessity of a global sustained Integrated Marine Debris Observing System (IMDOS)
- Promote the building of a global IMDOS community

[6] https://www.eu4oceanobs.eu/ocean-decade-lab-satellite-activity/

- Encourage the cooperation among scientists and between scientists and stakeholders such as policy makers and mitigation actors.

It is important to note that the meeting creates an important opportunity to streamline the development of IMDOS coordination and initial actions with the needs of the recently convened UNEP GPML Community of Practice on Data Harmonization. There, EuroSea also provides coordination support through Artur Palacz who together with representatives of GEO Blue Planet and NOAA NCEI leads the Ocean & Coasts section of this Community of Practice.

2.4. Reconciling the SDG indicator and EOV frameworks for marine debris

Community workshop on marine debris indicators and their evolution

Artur Palacz from IOPAN, on behalf of EuroSea, initiated community consultations on the development of a new Marine Plastics Debris EOV during the community workshop on "Marine Debris Indicators: What is Next?"[7] held in December 2019 in Brest, France, organized by IEEE France and GEO Blue Planet. Second in the series of workshops, this event aimed to strengthen the link between observation, extracted information, and decision and policy making related to the problem of marine litter pollution. Participation in the workshop meant that IOPAN took part in further development of a community focusing on monitoring and measuring of marine debris, thus enhancing the project's capacity to support the establishment global coordination of IMDOS.

The workshop, which was attended by many experts in marine litter policy development, monitoring, remote sensing technology development and modelling, was a first opportunity to introduce the objectives of EuroSea, the concept of EOVs and the capacity of GOOS to coordinate ocean observations to the international marine litter community. The community welcomed the proposed EuroSea plans to support implementation of the IMDOS vision with strong enthusiasms noting the outstanding need to establish better global coordination of monitoring and inclusion of marine debris observing requirements in the EOV framework.

Global frameworks for setting priority variables and indicators

One of the sessions of the Marine Litter WG co-led by EuroSea during the 2020 OBPS workshop was entitled "Global frameworks for setting priority variables and indicators." Led by Heidi Savelli-Soderberg (UNEP, Kenya), Jilian Campbell (CBD, Canada), Sanae Chiba (JAMSTEC, Japan) and Artur Palacz (IOCCP/IOPAN, Poland), the session included discussions spanning two days with the goal to discuss how to effectively reconcile requirements for best practices to monitor marine litter in the context of the evolving UN SDG indicator framework and the Essential Ocean Variable framework of GOOS.

Participants called for strengthening of ties between GOOS and UNEP to reconcile the differences between indicator-based monitoring and EOV-based sustained ocean observations, in the marine litter domain in particular. The launch of the UN Decade of Ocean Science for Sustainable Development was recognized as a unique opportunity to fill this gap across a number of societal issues related to the ocean.

Workshop discussions focused on the future prospect of coordinated global marine litter monitoring, pointing at the main role of UNEA in the process, having the mandate to coordinate global monitoring of marine debris. Critical gaps in the current state of global monitoring were highlighted against current policy and scientific requirements, pointing at the need for new monitoring initiatives which could be facilitated

[7] https://www.gstss.org/2019_Brest/

through engagement of coordinated observing networks of GOOS, guided by the new Marine Plastics Debris EOV requirements. Floating microplastics and plastics ingested by marine biota were examples of two indicators which were recommended for expansion of observations - and indeed considered as sub-variables of the presented first version of the Marine Plastics Debris EOV (see Section 2.5).

The workshop session concluded with the following recommendations which provided significant input and rationale for developing the Marine Plastics Debris EOV along with the initial Specification Sheet:

- There is a need to better communicate between and reconcile existing global (environmental-based) monitoring frameworks (SDG and CBD indicators) with the science-based ocean observations framework (Essential Ocean Variables).
- It is recommended that global monitoring of marine litter be expanded beyond current list of level-1 (global) SDG indicators considering those indicators and methodologies with potential for global upscaling and addressing gaps in current knowledge (e.g. seafloor litter, microplastics, ingestion by biota such as sea turtles).
- Developing Marine Plastics Debris as an Essential Ocean Variable could help establish coordination of science-based observations, in line with a vision for an Integrated Marine Debris Observing System (IMDOS).
- Exploring the potential for other basin-scale operations via established GOOS-coordinated observing networks is recommended.
- Seek endorsement and support for a roadmap for establishment of the marine microplastics monitoring and data hub - an initiative by Japan and G20.
- Establish and fund a global coordination of marine litter monitoring under the UN Ocean Decade for Sustainable Development.

Standard vocabularies and ontologies

Reconciling the SDG indicator and EOV requirement setting frameworks relies on the use of common language and terminology. To this end, IOPAN's Artur Palacz was invited to join UNEP GPML Ontology Community of Practice which in partnership with IOC-UNESCO's OBPS is developing standard vocabularies and ontologies to define key terms in managing information associated with marine litter and plastic pollution, and thus support the SDG 14.1 indicator framework development. It was agreed that pending the publication of the standard vocabulary and ontology, EuroSea will promote its use in the development of the Marine Plastics Debris EOV Specification Sheet and associated documents.

2.5. Marine Plastics Debris EOV Specification Sheet - version 1.0

Below is the initial version of the Marine Plastics Debris EOV Specification Sheet which was put together based on existing and published recommendations for global monitoring strategies, and based on extensive community consultations and workshops described above. Some elements of the Specification Sheet are incomplete, while others remain subject to ongoing expert discussions.

In the next stage, an open call for public consultation of this emerging Marine Plastics Debris EOV will be released, with subsequent presentation of the EOV for final approval by the GOOS Steering Committee.

Version: 1.0 - April 2022

Essential Ocean Variable Specification Sheet

Marine Plastics Debris

Global Ocean Observing System (2022). Essential Ocean Variable Specification Sheet: Marine Plastics Debris. GOOS Reference No *XX*; DOI: *[to be assigned]*

EOV Specification Sheet curated by:

Background & justification

Marine debris is defined as any persistent, manufactured or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment (UNEP, 2016).

Anthropogenic marine debris, particularly plastic, poses a growing threat to marine ecosystems, maritime activities, and the wellbeing of the ocean users. Once at sea, marine debris is dispersed by physical processes such as ocean currents, sinks to the seafloor and enters the food web. Marine debris from manufactured polymers, commonly known as plastics, may persist for decades and possibly for centuries.

Marine debris is a hazard to marine life and potentially also to human health through the contamination of marine resources: large objects cause entanglement and shelter invasive species, whereas smaller pieces, when ingested by marine animals cause starvation and can be vectors for pollutants and pathogens.

Marine debris is thus a transboundary, multi-dimensional problem with economic, environmental, cultural, and human health risks and associated costs. To address this issue, the United Nations established the Sustainable Development Goal (SDG) 14, “Life Below Water” and Target 14.1: “by 2025, prevent and significantly reduce marine pollution of all kinds, from land-based activities, including marine debris and nutrient pollution”.

To achieve the ambitious goals of the UN SDGs and of the UN Ocean Decade “Clean ocean” challenge, there is a critical need for global marine debris monitoring and understanding its transport, which are the key pillars for successful mitigation and policy strategies.

The Marine Plastics Debris EOV specifies global scale measurements and recommended methods according to societal and scientific requirements. The proposed EOV sub-variables complement and expand the current set of level 1 (global) SDG 14.1.1b indicators, in line with state-of-the-art guidelines for global monitoring of marine debris published by GESAMP WG40. Current observing capacity for measuring these variables as well as current data management efforts on regional to global scale are reviewed, along with a catalogue of key references.

Development of Marine Plastics Debris EOV relies on the successful development of global coordination of an Integrated Marine Debris Observing System (IMDOS) which is being established with support from GOOS and GEO Blue Planet among other partners. IMDOS aims to build up, develop and apply a global and integrated observing system dedicated to marine debris with harmonised observing tools, approaches, and products while embracing the full complexity of the composition, dynamics, and impacts. The synthesis of a variety of observations is thus required to provide long-term monitoring of anthropogenic marine debris and to support operational activities and strategic planning to mitigate impacts. IMDOS relies on the intelligent and dynamic integration of shoreline and at-sea in situ observations, remote-sensing, and numerical modelling, thus supporting gradual increase of readiness levels in Marine Plastics Debris EOV requirement setting, observing capacity and data management.

[suitable Image to be selected]

Picture caption
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EOV Information

Name of EOV		Marine Plastics Debris
EOV sub-variables		• beach litter: abundance per type and size category • floating* microplastics: abundance, weight • floating macroplastics: abundance • seafloor litter: abundance per type and size class (macro, micro) *Additional sub-variables under consideration:* • Macroplastics in biota (ingestion by seabirds, fish, sea turtles) • Microplastics in biota (ingestion by seabirds, bivalves) **Floating refers to both surface and water column*
Corresponding other Essential Variables	ECV	-
	EBV	-
	Other	
Relevant global indicators	SDG	14.1.1.b: plastic debris density
	CBD	
	Climate	
	other (e.g. regional such as MSFD)	MSFD Descriptor 10 (Litter) Indicators
Other derived products		*to be determined*
Supporting variables		Ocean Surface Stress EOV (wind stress); Surface Currents EOV; Sea State EOV (significant wave height); Cloud cover
EOV Specification Sheet curator		International Ocean Carbon Coordination Project (IOCCP) & Integrated Marine Debris (IMDOS) Interim Steering Committee Contact at: ioccp@ioccp.org

Requirements setting: Phenomena

GOOS Applications		Ocean Health							
Scientific & policy questions		• What are the magnitude, location and temporal variability of the sources and pathways into the marine environment of marine plastic debris? • What are the abundance, horizontal distribution and composition of marine plastic debris, and how do these attributes change over time? • Where does marine plastic debris tend to accumulate? • How is marine plastic debris transported and what are the dominant physical processes influencing its fate? • What role do biological, chemical and photochemical interactions play in controlling the movement and degradation of marine plastic debris?							
Readiness level									
Phenomena to capture		**Accumulation**				**River discharge**	**Spills**	**Air-sea fluxes (wet/dry deposition)**	**Extreme events**
		shoreline	**ocean**	**seafloor**	**biota**				
Coverage	horizontal	global coastal	global	global	global	global coastal	global	global	global
	depth	-	surface to deep ocean	seafloor	surface to deep ocean	surface ocean	surface ocean	surface ocean	surface ocean
Spatial scale/resolution [order of magnitude]	horizontal	1000 km	100-1000 km	100-1000 km	species-dependent	100 km	100 km	1-250 km	
	vertical	-	?	-	-	-	-	-	-
Temporal scale/resolution									
Signal to capture		# of items per 100m beach length (Van Loon et al. 2020)	abundance/ weight per area per year	abundance/weight per area per year	items / ind % species	abundance/weight per year		particles/m3 per unit time	abundance per area per event

EOV subvariables required	beach litter	floating microplastics	seafloor litter	macrolitter in biota	floating macrolitter floating microplastics	floating macrolitter	floating microplastics	floating macrolitter floating microplastics
Other EOVs required/relevant		Ocean surface stress; Surface currents;	Macroalgal canopy cover & composition; Seagrass cover & composition	Marine turtles, birds, mammals abundance and distribution		Ocean surface stress; Surface currents		
Relevant global indicators	*SDG 14.1.1b*	*SDG 14.1.1b*	*SDG 14.1.1b*	*SDG 14.1.1b*	*SDG 14.1.1b*	*SDG 14.1.1b*		

Current observing elements

(networks and communities of practice)

Observing element	Approach/platform	Visual: human observers	Ship-based: net tows	Ship-based: Continuous Plankton Recorder	Visual: ROV surveys	Ship-based: underway pumps	Visual: human observers	Visual: SCUBA diver surveys
	Readiness Level	mature	mature	mature	pilot	pilot	pilot	pilot
	Coordinated observing network(s)/ community (if any)	Regional only: [US] NOAA Marine Debris Monitoring and Assessment Project (MDMAP); [EU] Marine LitterWatch; [AUS] Australian Marine Debris Initiative	Ministry of Environment Government of Japan (MOEJ) Data Sharing Project	Global Alliance of CPR Surveys (GACS)	Regional only: [Asia] JAMSTEC; [EU] MSFD Tech Group on Marine Litter	-	Regional only: [EU] JRC RIMMEL project	Regional only: [EU] Project AWARE; MSFD Tech Group on Marine Litter
	OCG network specification sheet	-	-	-	-	-	-	-
	EOV sub-variables measured	beach litter	floating macroplastics floating microplastics	floating macroplastics	seafloor litter	floating microplastics	floating macroplastics	seafloor litter
	Phenomena measured	accumulation: shoreline	accumulation: surface ocean; extreme events	accumulation: surface ocean	accumulation: deep seafloor	accumulation: surface ocean	river discharge	accumulation: shallow seafloor
	horizontal coverage	global: seashore	global	global	regional: coastal ocean	global open ocean	regional: river outlets	regional: coastal ocean

Standard spatial sampling	depth coverage		surface only	10 m	seafloor		surface	0-30 m
	resolution							
	operating period							
Supporting variables measured								
Measurement technique/ sensor type		manual counts, visual survey	Manta net, neuston net	macroplastic entanglement on marine sampler - Ostle et al. (2019)		throughflow microplastics autosampler; lab or or onboard analyzer	smartphone enabled visual survey	visual survey, rectangle area/ line transect
Accuracy/uncertainty								
Status of the observing network								
Reporting mechanism								

Future observing capacity

Observing approach/platform	Remote sensing: satellite	Remote sensing: airborne	Autonomous: wave gliders	Visual: human observers	Ship-based / Fixed-point
What is the novel aspect of this observing approach?	Potential global coverage of surface floating macroplastics, shallow seafloor macrolitter and microlitter (through synthetic aperture radar).	Potential global coverage of surface floating macroplastics (and shallow seafloor macrolitter)	Video imagery of surface and subsurface macrolitter; deployable on the growing number of autonomous underwater and surface vehicles.	Measuring microplastics and macroplastics in biota	Monitoring of microplastics in the air, and their flux into other compartments over the ocean.
How does this novel aspect impact our observing capacity?	Unprecedented spatio-temporal coverage of floating plastic patches in the global open ocean		Near-real time monitoring of oceanic environments.	Estimate accumulation in marine organisms.	Enables to track plastic pathways and better constrain the budget.
Comments or references	IOCCG Task Force on Remote Sensing of Marine Litter and Debris	IOCCG Task Force on Remote Sensing of Marine Litter and Debris	MSFD TGML (2013)	MSFD TGML (2013); GESAMP (2019)	Systematic review of methods through EU EUROqCHARM project

Data and information access

Observing approach/ platform	Oversight & coordination	Data Quality Control	Data repositories		Data products
			Near Real-Time Data stream delivery	Delayed-mode data delivery	
Ship-based: net tows	MOEJ	MOEJ Data Sharing Project		MOEJ Global Data Hub (to be launched)	Surface ocean floating microplastic synthesis product (Isobe et al., 2021)
				EMODnet Chemistry: Pan European Marine Litter Database (MLDB)	
				NOAA National Centers for Environmental Information (NECI) Marine Microplastics	
				LitterBase	
readiness level:					
Ship-based: CPR surveys	GACS	GACS		CPR Survey Data	
readiness level:					
Ship-based: underway pumps				EMODnet Chemistry: Pan European Marine Litter Database (MLDB)	Global surface ocean floating microplastics from the Volvo Ocean Race (Tanhua et al., 2021)
				NOAA National Centers for Environmental Information (NECI) Marine Microplastics	
readiness level:					
Visual: human observers				EMODnet Chemistry: Pan European Marine Litter Database (MLDB)	

				NOAA Marine Debris Monitoring and Assessment Project Database	
				LitterBase	
readiness level:					
Visual: ROV surveys				JAMSTEC Deep-sea Debris Database	
				EMODnet Chemistry: Pan European Marine Litter Database (MLDB)	
readiness level:					
Remote sensing: satellite	IOCCG			List of online repositories and published datasets available at: https://ioccg.org/rsmld-activities-datasets/	
readiness level:	concept				

References

Guides and best practices	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
	EU MSFD Technical Subgroup on Marine Litter (2013). Guidance on Monitoring of Marine Litter in European Seas; Joint Research Centre of the European Commission Report; doi:10.2788/99475
	Michida, Y., et al. (2019). Guidelines for Harmonizing Ocean Surface Microplastic Monitoring Methods. Ministry of the Environment Japan, 71 pp.
Standards and reference materials	Pilots under development as part of EU EUROqCHARM project: https://www.euroqcharm.eu/en
Other reference documents	EU threshold for beach litter monitoring: Van Loon, W., et al. (2020). A European threshold value and assessment method for macro litter on coastlines, EUR 30347 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21444-1 (online), doi:10.2760/54369 (online), JRC121707.
	EU MSFD Joint list of macrolitter categories: https://mcc.jrc.ec.europa.eu/main/dev.py?N=41&O=459
	Riverine Litter observations (RIMMEL): https://mcc.jrc.ec.europa.eu/main/dev.py?N=simple&O=380&titre_page=RIMMEL&titre_chap=JRC%2520Projects
	IOCCG Task Force on Remote Sensing of Marine Litter and Debris Terms of Reference: https://zenodo.org/record/4446238#.YCbB2nko-Ul
	Martínez-Vicente, et al. (2019). Measuring Marine Plastic Debris from Space: Initial Assessment of Observation Requirements. Remote Sens. 2019, 11, 2443. https://doi.org/10.3390/rs11202443
	Maximenko N, et al. (2019) Toward the Integrated Marine Debris Observing System. Front. Mar. Sci. 6:447. doi: 10.3389/fmars.2019.00447
	Smail E.; et al. (draft). A Global Platform for Monitoring Marine Litter and Informing Action; https://geoblueplanet.org/global-platform-for-monitoring-marine-litter-and-informing-action/

2.6. EOV curation process - EuroSea legacy

The presented version of the Marine Plastics Debris EOV remains under joint curation of the International Ocean Carbon Coordination Project (IOCCP), acting as the Biogeochemistry Panel of Experts of GOOS, and the newly established IMDOS Interim Steering Committee. The EOV will be officially released for broad public consultation in second half of 2022, and subsequently presented for official approval by the GOOS Steering Committee.

As mentioned in the introduction, the Marine Plastics Debris EOV is expected to evolve rapidly in response to changing societal and scientific requirements and in response to rapid innovation in observing capacity, both for sampling methods and design and analytic procedures. Therefore, it is critical to ensure an adequate body with authoritative guidance committed to further the development of and curation of the new EOV on Marine Plastics Debris.

To ensure legacy of the EuroSea project beyond its lifetime, the IMDOS Interim Steering Committee has among its proposed Terms of Reference the task to:

"Develop and regularly review a set of specifications, implementation plans, and progress metrics for measurements included under the Marine Plastics Debris Essential Ocean Variable, and as needed to inform or develop new global indicators (e.g. SDG 14.1.1.b)."

3. Harmonization of methods and common sampling protocols for Marine Plastics Debris EOV

As part of the objective to develop capacity for sustain ocean observations of marine plastics and a contribution to IMDOS, EuroSea's Task 1.1.3 intended to:

> (i) foster the development of common sampling protocols to promote harmonized, and where possible standardized, monitoring methods, and
>
> (ii) enable shared and co-designed observations of Marine Plastics Debris EOV with other relevant EOVs through common sampling protocols adopted by coordinated observing networks or communities of practice of GOOS.

In relation to (i), EuroSea collaborated closely with the Co-Chairs of GESAMP WG40 and Co-Chairs of MSFD Technical Group on Marine Litter (TGML) to agree on how EuroSea can best promote recommended sampling protocols for regional and global monitoring of marine litter and debris, and contribute to development of new common protocols. Section 3.1 and 3.4 describes EuroSea's contribution to this objective.

In relation to (ii), EuroSea identified several key opportunities for augmenting existing coordinated ocean observations with marine plastics debris sampling protocols based on the recommendations of the MSFD TGML, the GESAMP WG40, and based on consultations with members of GOOS Panels of Experts, members of other GOOS structures, and the ocean observing community at large. As identified in the EuroSea Action Plan for IMDOS, one of the key initial outcomes of IMDOS should be an analysis of feasibility and cost of adding a marine debris component to operations of established networks and communities of practice of GOOS. Such analysis, modelled after the SCOR WG 154 report[8], would focus on:

- Net tow measurements (Manta, neuston) of surface ocean floating microplastics on ships servicing coastal buoys and moorings, commercial vessels or other ships of opportunity, based on Guidelines for Harmonizing Ocean Surface Microplastic Monitoring Methods (Michida et al., 2019)
- Semi-automatic underway measurements of surface ocean floating microplastics on research vessels, commercials vessels and racing yachts
- Video camera observations of surface macrolitter (e.g. littercam) on ships of opportunity, recreational sailing vessels, or potentially autonomous platforms (e.g. wave gliders)
- Co-designed visual surveys (scuba, ROV) and standard sampling protocols for monitoring shallow seabed macrolitter and macroalgal communities
- Co-development of remote sensing products for floating macrolitter and coastal marine habitats and biodiversity (e.g. macroalgae, seagrass).

In Sections 3.2-3.3 we detail the progress towards such ocean observing co-design and development of common sampling protocols in a few of the areas listed above.

It should be noted that addressing all of the opportunities for EOV co-design was beyond the scope of EuroSea, and that the main focus was placed on coordinated actions to develop common coastal biodiversity and seafloor litter sampling protocols in Europe where there is a major gap in available data and at the same

[8] https://repository.oceanbestpractices.org/handle/11329/1201

time, sampling design is simple and not costly to implement if combined with existing coastal biodiversity surveys.

3.1. Global priorities for harmonization and standardization of monitoring

In the initial stages of the project, EuroSea convened the international Marine Litter Working Group during the IV Ocean Best Practices System (OBPS) workshop in September 2020 (see details in sections above) with a dedicated session on "Towards standard sampling protocols" led by two Co-Chairs of GESAMP WG40: Francois Galgani (Ifremer, France) and Alexander Turra (Oceanographic Institute, University of São Paulo, Brazil). The objective of that session was to discuss the prospects for establishing first standard sampling protocols for marine litter while considering many challenges and types of constraints when recommending and adopting common methodologies.

The session primarily built on the then recently published "Guidelines or the monitoring and assessment of plastic litter and microplastics in the ocean" (GESAMP, 2019) but also on UN Regional Action Plans, and other documents which addressed the challenge to consider environmental, technical or even ethical constraints when recommending and adopting common methodologies.

Around 30 attendees from around the world took part in an open, virtual and interactive 2.5-hours long community discussions guided by the two leading global experts in the field. The group shared and discussed many issues and challenges behind harmonization and standardization of methods in response to the different criteria and constraints comprehensively described in the GESAMP monitoring guidelines.

Among the top criteria and constraints considered were:

Scientific:

- Scientific information must be accessible and accepted/recognized by the scientific community
- Possible interferences are managed

Methodological:

- Protocols have been referenced, tested, compared and validated by the community of specialists
- The existence of bias in the measurement (natural fibers, contamination, etc.) must stop the use of a protocol
- Data is collected according to recognized and validated procedures
- Reproducibility and representativity must be guaranteed (standard operational procedures with quality assurance and guides)
- Standardization must be reached for regular monitoring

Logistical:

- The existence of good logistical practices and common approaches must favour the comparability and harmonization of results

Complete recording of this session is available through the OBPS YouTube Playlist[9], and a detailed written report of this session can be found in Volume 2 of the OBPS IV Workshop Proceedings (Simpson et al., 2021).

[9] https://www.youtube.com/playlist?list=PLkuDz7rC6Mb9p-xIXqmJ8iKfVoazIa5Tr

The following five key recommendations were put forward as an outcome of this session:

1. Short-list the most relevant indicators for global scale monitoring. Possible suggestions included: Beach litter; Sea floor litter by diving (MPAs) / ROV; Microplastics (floating & sediments); Ingested litter by sea turtles/mussels.
2. Elaborate formal guidelines for global Marine Litter indicators
3. Recommend and support research for methods enabling large scale assessments (models, remote sensing, etc.)
4. Elaborate best practices dedicated documents for each of the relevant indicator with consideration to the various steps of implementation process (strategy, protocols, analysis, data check, database, baseline, thresholds, reporting)
5. Consider technical workshops to harmonize approaches/ protocols for each of the relevant global scale indicators, and define the best possible approaches to manage data

Subsequent EuroSea work supported implementation of these recommendations, in particular #1 and #5, through:

- Selecting sub-variables for the emerging Marine Plastics Debris EOV in line with expert recommendations and reconciled with the SDG 14.1.1b indicator development (see Section 2.4)
- Organizing a joint workshop with the European macroalgal observing community to establish common sampling for MSFD reporting (see Section 3.2)
- Providing expert and stakeholder advice for the global data sharing project of the Ministry of Environment, Government of Japan (see Section 3.3)

3.2. Common sampling protocol for shallow seafloor macrolitter and macroalgae

Rationale

The process of developing Marine Plastics Debris EOV as a new type of human pressure EOVs revealed significant common observing requirements with at least two existing EOVs: the Macroalgal Canopy Cover & Composition EOV and the Seagrass Cover & Composition EOV. Recent establishments of the Global Ocean Macroalgae Observing Network (GOMON; Miloslavich & Walsh, 2019) and the SCOR Working Group C-GRASS: Coordinated Global Research Assessment of Seagrass System[10] gave a promise of sustained global observations of macroalgae and seagrass habitats - two coastal habitats which can act as accumulation zones for marine plastics debris, and which can potentially be harmed by it through e.g. abandoned, lost or otherwise discarded fishing gear, or other types of macro and micro litter.

The global relevance and potential of combining marine debris and biodiversity monitoring programs for the benefit of developing IMDOS was highlighted in a peer-reviewed article published in the inaugural supplement on ocean observing in Oceanography, an official magazine of The Oceanography Society. The paper by Maximenko, Palacz et al. (2021) was a direct EuroSea contribution.

In Europe, benthic fauna and marine litter monitoring programs operate side by side under the same Regional Seas Conventions but are not well integrated with each other. This is in spite of the fact that both types of

[10] https://scor-int.org/group/158/

monitoring are required to fulfil the MSFD requirements of Good Environmental Status with macroalgae listed under Descriptor 5: Eutrophication, and seafloor macrolitter under Descriptor 10: Litter.

Underwater visual surveys with SCUBA/snorkelling are the most common method to estimate both marine litter density on shallow (<20 m) seafloor and to estimate macroalgal canopy cover and its status. Video image via ROVs or AUVs are another common method applicable to both types of surveys There are well-defined protocols in place as described in the MSFD TG ML 2013 Guidance on Monitoring of Marine Litter in European Seas (Section 5.4 of that report).

While macroalgal surveys are common across the EU and beyond, shallow seafloor macrolitter surveys remain very scarce. A pilot study to conduct SCUBA visual surveys of seafloor litter was initiated as part of project AWARE - a programme using volunteer divers. Unfortunately, the effort was stopped in early stages of development by the outbreak of the COVID pandemic.

In their 2013 Guidance on Monitoring, MSFD TG ML recommended that:

> *"Considering opportunities to couple monitoring efforts may be the best approach to monitor litter on the sea-floor. There may be other opportunities to couple marine litter surveys with other regular surveys (monitoring in marine reserve, offshore platforms, etc.) or programmes on biodiversity." (MSFD 2013; p.64)*

Successful examples of such integration exist in Europe, notably in Estonia where marine litter surveys have already been combined with existing benthic and shoreline vegetation monitoring capacity for the past couple of years. This is supported by a number of recently completed and ongoing projects, covering the water areas of harbours as well as marine protected areas surrounding remote Estonian Islands. Apart from the macro and microlitter surveys more commonly done across Europe, there is also comprehensive data from visual surveys performed by diving and/or ROVs. Details can be found in the report "Monitoring of seafloor litter in coastal sea of Estonia, development of methodology and assessment for MSFD reporting" (TÜ EMI, 2018; available in Estonian), and by contacting Tiia Möller-Raid at the University of Tartu in Estonia.

Finally, it should also be noted that as floating macro litter patches (SDG Indicator 14.1.1b) tend to aggregate around benthic fauna, rapidly developing remote sensing detection methods (drones, satellites) could equally benefit global monitoring and assessment of litter and marine habitats.

EuroSea Workshop on Macroalgae

On 23-25 November 2021, EuroSea organized an online community workshop "Towards a Coordinated European Observing System for Marine Macroalgae." The event brought together several dozen participants mostly from Europe but also from North America, North Africa and Asia who discussed observation strategies, data standards and sharing, operating procedures for observations in this important ecosystem and economic area, as well as the potential for integration with the emerging Marine Plastics Debris EOV requirements.

In consultation with a group of marine litter experts from MSFD TGML and the IOCCG Task Force on Remote Sensing of Marine Litter and Debris, the workshop organizers identified several threads to discuss as opportunities for how coordinated macroalgal and shallow seabed litter monitoring would jointly support the requirements of MSFD D5 on Eutrophication and D10 on Litter. In particular, the workshop session on integration with plastics monitoring discussed practical steps towards:

- Harmonizing sampling protocols and sharing survey designs for visual monitoring methods (e.g. diving, ROVs) common to both macroalgal and seafloor litter monitoring
- Aligning data flows and products to support multiple MSFD requirements through EMODnet data management and dissemination facilities
- Setting common requirements for remote sensing product development (e.g. as part of future ESA projects)

These objectives directly addressed gaps and followed recommendations from the Guidance on Monitoring by the MSFD TGML. During the workshop the experts discussed both opportunities and challenges behind integrating two monitoring programs and adopting a common sampling protocol to facilitate MSFD reporting. The opportunities can be summarized as follows:

- Observing methods same as for macroalgae: visual scuba diving and/or ROVs
- Minimal requirements for seafloor macroplastics (>2.5 cm) to be included in the SOPs:
    - Rectangle area/line transect for counting litter items
    - Reported in density of litter items per category per m2/km2 (distance sampling method)
- Harmonized list of litter categories for standardized monitoring are available
- Advanced development of marine litter ontology to support indicator frameworks (EMODnet, SDG)
- EMODnet and OBIS ready to ingest marine plastics data, although visual survey data products in EMODnet are so far in planning only
- Interaction between plastics pollution and macroalgae constitutes an open research question which motivates additional parallel sampling for research purposes, thus further supporting regular monitoring
- There is confirmed interest from a few monitoring groups to augment existing efforts with seafloor litter surveys
- Possible retrospective analysis of archived imagery from benthic fauna surveys to estimate trends in macroplastic and other debris accumulation.

Challenges behind the integration can be summarized as follows:

- A different focus is required for visual surveys with litter items being as small as 2.5 cm. This proved very challenging when attempting past integration with marine mammal surveys.
- Many macroalgal sites do not show macrolitter accumulating so far which means that not all areas might require regular observations of both sets of indicators/EOVs
- Main research interest lies in the interaction between microplastics & macroalgae where accumulation in the seabed and adhesion on the organisms was already documented. However, in these studies there is no logistic benefit of combining surveys.
- It is not possible to integrate sampling requirements for eDNA and microplastics with very large water volumes required for the latter.

The workshop session on integration and common SOPs concluded with the following recommendations:

1. Establish initial pilots within interested macroalgal monitoring initiatives in collaboration with the MSFD TGML and EMODnet Chemistry for data ingestion).
2. If possible, combine joint surveys based on common SOPs with macrolitter clean-up operations.

Initiating a pilot based on common SOPs

Work on a pilot project to incorporate shallow seafloor macrolliter surveys into existing macroalgal biodiversity surveys in Europe began immediately after the workshop thanks to Nova Mieszkowska, the lead PI of the Marine Biological Association (MBA) MarClim project[11] which has the most spatio-temporally extensive time-series for rocky intertidal organisms globally, with data stretching back to the 1950s for native species of macroalgae and invertebrates. Nova expressed her willingness to adjust her sampling surveys and protocols for macroalgae surveys in UK and northern France monitoring sites to enable parallel collection of seafloor litter. This process is in direct consultation with the MSFD TGML experts.

Successful development of this pilot will also depend on developing automatic and integrated data ingestion routines and common metadata standards related to visual SCUBA observations within EMODnet. Currently, EMODnet Biology ingests data from visual macroalgal surveys but EMODnet Chemistry does not yet ingest data from visual SCUBA surveys of shallow seafloor litter, only from deep-sea trawls. EuroSea will continue to promote the need for such automatic data flows to facilitate routine observations of shallow seafloor macrolitter.

3.3. Towards a coordinated observing network for surface floating microplastics

GOOS strives to increase the readiness level of coordinated observing capacity and data management of floating microplastics after the recommendation to include this parameter as a sub-variable of the Marine Plastics Debris EOV. As part of the objective to expand a global network of marine debris observations through enhanced platform sharing and coordination of collocated marine litter, oceanographic and/or ecological observations, EuroSea has been working with other organisations to establish a coordinated observing network for surface floating plastics. Such a coordinated network will build on the existing harmonization and coordination initiatives led by JAMSTEC in Japan and the MSFD Technical Group on Marine Litter in Europe, and will benefit from parallel efforts to establish a global data management and synthesis product development on surface floating microplastics led by the Ministry of Environment, Government of Japan (MOEJ) supported by the G20 countries.

Based on Guidelines for Harmonizing Ocean Surface Microplastic Monitoring Methods (Michida et al., 2019) and using data provided by researchers and monitoring program managers from around the globe, MOEJ has been able to establish a comprehensive data management system and data platform which will be publicly launched in a few months. This tremendous effort, supported by the global community of experts and data providers, also aims to establish interoperability with other leading databases on microplastics in water, i.e. EMODnet Chemistry in Europe and NOAA NCEI in the US, thus supporting a federated data management model advocated for by EuroSea on behalf of GOOS.

IOPAN's Artur Palacz was invited to join a series of International Expert Meetings on Marine Plastic Litter Monitoring Data Sharing Project of MOEJ, attending first as an observer in December 2020, and then as an expert in February 2021, November 2021 and in March 2022. The goals of the workshops were to seek guidance from the international community on the evolution of the MOEJ Global Plastics Data Hub and global data synthesis product on surface floating microplastics, the first version of which was published in 2021 (Isobe et al., 2021).

[11] https://www.mba.ac.uk/projects/marine-biodiversity-and-climate-change-marclim

In October 2021, EuroSea facilitated a first online meeting between MOEJ, representatives of Japanese research institutions and GOOS Co-Chairs and members of GOOS Structures. The parties agreed to further pursue discussions on how to develop collaboration between MOEJ and GOOS to advance marine debris monitoring and data management. The goal of the meeting was to introduce the concept and benefits of creating a coordinated observing network, and to highlight the fact that the MOEJ data sharing project has de facto led to the formation of an informal community of practice around surface floating microplastics.

With a dedicated data management group and agreement to follow harmonized data protocols, this effort exhibits strong potential to become a coordinated observing network meeting the GOOS Observations Coordination Group (OCG) network standards (Fig. 1). EuroSea continues to promote further collaboration between GOOS and MOEJ to elevate the harmonized monitoring guidelines to an internationally-agreed standard sampling protocol and development of a coordinated observing network for surface floating microplastics. OceanOPS, joint WMO-IOC centre for oceanography and marine meteorology would provide support as planned in its strategy[12] and foster integration within GOOS and synergies with established networks. Future survey design would consider the needs of remote sensing and modelling communities, as expressed in the requirements set under the Marine Plastics Debris EOV. The network status, progress and performance would be visualized through the OceanOPS real-time dashboard and toolbox. OceanOPS would help to develop clear implementation targets, to enable appropriate Key Performance Indicators and enrich its metadata standard[13] according to the EOV requirements. Moreover, OceanOPS can support operations at sea and bring opportunities for ship time to this network, as a vital element of IMDOS.

Figure 1. GOOS OCG network criteria, also applicable to observations of all EOVs.

Such an observing network would also bring together different citizen science initiatives aimed at microplastic and/or macroplastic observations from non-commercial (sailing and other recreational) vessels. This activity will be included in the larger cooperation effort led by OceanOPS within the UN decade project

[12] https://www.ocean-ops.org/strategy/
[13] https://www.ocean-ops.org/metadata/

"Odyssey"[14] to unlock the potential of civil society and the private sphere to contribute to IMDOS and the GOOS. It is important to note that to this day, there exist no guidelines for harmonized monitoring and sampling protocols for underway microplastic sampling, and that the data collected by sailing vessels is not yet directly comparable with more traditional net-tow sampling data aggregated and harmonized by MOEJ. This is a challenge which the proposed observing network would need to tackle, with guidance from both OceanOPS and IMDOS.

Furthermore, EuroSea has already supported new data collection efforts which would help enlarge the current monitoring capacity for surface floating microplastics. For example, through a successful application to Ponant Cruises, a pilot microplastic sampling will take place in the Arctic in summer 2022 aboard Ponant's icebreaker Le Commendant Charcot, with tentative plans to repeat the sampling over the next 4 years. Sampling will be performed using the harmonized protocol recommended by Michida et al. (2019), and the collected data will be submitted using standardized metadata and data formats developed by MOEJ and OceanOPS.

3.4. Stakeholder advise for monitoring standards development in Europe

EuroSea supports the development of harmonized methods and standards through support for the EU EUROqCHARM project. IOPAN's Artur Palacz accepted an invitation to serve on EUROqCHARM's Stakeholder Advisory Board. The project wants to analyse and evaluate existing methodologies for plastic pollution assessment, harmonize them on a European level, and develop blueprints for monitoring standards among other things. That is why the project unites 15 key actors involved in studying and monitoring plastic pollution in Europe.

EuroSea supported Artur Palacz to actively participated in all stakeholder webinars and meetings to provide advice on how to align the project's work and outcomes with the priorities of global monitoring and other international initiatives towards harmonized and standardized sampling for plastics in the ocean.

EuroSea will ensure that relevant outcomes from EUROqCHARM, along with MSFD TGML's expected revised guidelines for marine litter monitoring in the EU, will inform the further development of Marine Plastics Debris EOV when it comes to common sampling protocols.

Conclusion

This deliverable describes the successful development of Marine Plastics Debris as a new type of EOV which responds to the growing societal demand for sustained observations of human pressure on the ocean. The report describes in detail how EuroSea fulfilled its Task 1.1.3 by bringing together different international organizations, institutions and expert working groups with a mandate and capacity to address different elements of monitoring marine plastic debris pollution, and by forming new partnerships and an international coordinating body to provide future guidance on implementing the ambitious vision for an Integrated Marine Debris Observing System (IMDOS). Key collaborations were initiated through this work, highlighting the importance of GOOS and GEO Blue Planet providing joint coordination for IMDOS development at its conception, collaboration between GOOS and UNEP GPML towards creating IMDOS as a backbone observing system to support the GPML Digital Platform, initiated collaboration between GOOS and MOEJ to expand the

[14] https://www.oceandecade.org/actions/ocean-decade-odyssey/

global surface floating microplastics data sharing project towards creating an observing network according to GOOS OCG network standards, or the collaboration between GOOS and the IOCCG Task Force on Remote Sensing of Marine Litter and Debris to help bridge the gap between in situ monitoring capacity and the needs for remote sensing development.

The report also describes significant progress towards establishing key elements of IMDOS both to support MSFD requirements in Europe, and to support SDG requirements globally. This includes promoting and developing common sampling protocols and shared survey design for shallow seafloor macrolitter and benthic biodiversity monitoring, and provision of guidance on the topics of data harmonization an integration with existing ocean observing programmes. Further work is required to deliver internationally agreed standard operating protocols, pending the formation of relevant observing networks or communities of practices which would provide global coordination and oversight over each of the globally measurable marine plastics debris indicators, now also recognized and recommended for global monitoring though the Marine Plastics Debris EOV.

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