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Marine Pollution Bulletin

Marine beach litter monitoring strategies along Mediterranean coasts. A methodological review --Manuscript Draft--

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| Abstract: | Marine beach litter (MBL) represents a serious issue for marine life, coastal ecosystems, human health and several economical activities. The Mediterranean Sea is a semi enclosed basin particularly vulnerable to this problem. Its coasts are threatened by critical anthropogenic pressures that sum up with intensive fishing and shipping, and the slow turnover of its waters. In the last decades, several scientific and participative initiatives have been conducted to study, monitor and clean-up shorelines. These studies were generally characterized by differences in timing and frequency of the surveys, as well as in litter sampling, classification and analysis. This paper presents a systematic review of current literature concerning MBL monitoring strategies along the Mediterranean coasts. Scopus indexed studies are analysed to identify discrepancies and similarities among the applied protocols, understand where current gaps lie, and point out what would be needed to develop a basin-scale efficient monitoring for the Mediterranean Sea. |
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Marine beach litter monitoring strategies along Mediterranean coasts. A methodological review

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Abstract

Marine beach litter (MBL) represents a serious issue for marine life, coastal ecosystems, human health and several economical activities. The Mediterranean Sea is a semi enclosed basin particularly vulnerable to this problem. Its coasts are threatened by critical anthropogenic pressures that sum up with intensive fishing and shipping, and the slow turnover of its waters. In the last decades, several scientific and participative initiatives have been conducted to study, monitor and clean-up shorelines. These studies were generally characterized by differences in timing and frequency of the surveys, as well as in litter sampling, classification and analysis. This paper presents a systematic review of current literature concerning MBL monitoring strategies along the Mediterranean coasts. Scopus indexed studies are analysed to identify discrepancies and similarities among the applied protocols, understand where current gaps lie, and point out what would be needed to develop a basin-scale efficient monitoring for the Mediterranean Sea.

1. Introduction

Beaches were only recently recognized as ecosystems (McLachlan and Erasmus 1983) but the public perception is very far from this awareness (Rodil et al., 2022). Marine litter, particularly plastic pollution, are paradoxically helping in the valorisation of coastal habitats, being visible along the coast and triggering a strong perception that is important to take action to limit this kind of pollution (Lucrezi and Digun-Aweto, 2020). Marine litter is defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (MSFD GES Technical Subgroup on Marine Litter, 2013). It includes items or fragments that have been directly discarded on the beaches (e.g., coastal and beach tourism, recreational activities), those that have been somehow transported from land to the sea (e.g., households, agriculture, illegal dumping, input by rivers, wind and land run-off) and those coming from ocean-based sources (e.g., storm water overflows, off-shore industries, commercial shipping, fisheries, port activities and boating). Marine litter can also be transported over long distances by ocean currents before being deposited, so that it is found in all marine compartments such as beaches, on the shallow and deep seafloor, in the sea surface layer and in the water column, in sediments and sea ice (Law, 2017; Addamo et al. 2017). Thus, the marine environment can be considered as a sink in which anthropogenic litter accumulates (Van Acoleyen et al., 2013) coming from land-based and offshore sources (Veiga et al., 2016).

This implies that marine beach litter (MBL) found in a given area can be of local origin, can arrive from inland or can be transported from distant regions via ocean currents and the prevailing wind. Source and origin

1 identification is usually very difficult, especially when the litter items are fragments resulting from the
2 disintegration of larger items that spent long time along the pathways system. This is the case of microplastics
3 (i.e., small pieces of plastic litter < 0.5 cm in diameter, Arthur et al. 2009) that represent a serious global
4 problem causing harm to marine wildlife, coastal communities and maritime activities (Veiga et al., 2016).
5 Due to their persistent nature and their potential to cause undesirable effects, MBL has detrimental impact
6 on marine biota at different levels of biological organisation and habitats, environment, human health, as
7 well as economy (Gall and Thompson, 2015; Schneider et al., 2018; Agamuthu et al., 2019). Marine litter can
8 also act as a vector for spread of invasive species altering or modifying assemblages of species (Kießling et
9 al., 2015; Werner et al., 2016) or as vehicles for chemicals and contaminants, which may be absorbed on to
10 their surface (e.g., phthalates, polycyclic aromatic hydrocarbons (PAH), brominated flame retardants (BFR),
11 polychlorinated biphenyl (PCB), dichlorodiphenyltrichloroethane (DDT) – see Cole et al., 2011) and become
12 bioavailable accumulating along the biological food chain (Li et al., 2016; Fossi et al., 2018). Finally, MBL is
13 eyesore and aesthetically unpleasant causing landscape degradation and negative public perception leading
14 to a decline in tourism, and subsequent income loss, when washed ashore on beaches (Keswani et al., 2016;
15 Pasternak et al., 2017; Forleo and Romagnoli, 2021).

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21 Although no evidence of permanent garbage patches has been reported so far (Cózar et al. 2015), the
22 Mediterranean Sea has been recognized as one of the most vulnerable areas in the world by MBL (e.g.,
23 UNEP/MAP, 2015; Suaria et al., 2016; Fossi et al., 2019; Grelaud and Ziveri, 2020). It is a semi-enclosed basin
24 characterized by complex anti-estuarine circulation (Pinardi and Masetti, 2000; Cotroneo et al., 2021), slow
25 water overturning and the presence of intense gyres and mesoscale eddies (Aulicino et al., 2016; 2018) that
26 favour the potential accumulation of floating plastic debris (Suaria and Aliani, 2014; Zambianchi et al., 2017;
27 Compa et al., 2020). In addition, coastal population of nearly 150 million inhabitants and an intensive growing
28 tourism pressure, estimated in about one third of the world tourist presences (World Tourism Organization,
29 2018), make its coasts densely populated. Also, the Mediterranean Sea hosts about 15 to 30% of the global
30 shipping activity (UNEP/MAP, 2012) and represents an area of intense commercial fishing. This potential high
31 contamination goes hand to hand with a stream of adverse effects to marine ecosystems, public health and
32 socio-economic costs at local, regional and basin scales (Thompson et al., 2009; Wilcox et al., 2016; Solo-
33 Gabriele et al., 2016; Brouwer et al., 2017; Angiolillo and Fortibuoni, 2020).

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39 In this scenario, reducing litter in the Mediterranean coastal and marine environment is recognised as a
40 priority challenge to preserve the ecosystem and human health, and avoid adverse economic and aesthetic
41 impacts (Addamo et al., 2018). Specific measures aimed at preventing further inputs and reducing the
42 abundance of litter items need the determination of marine litter composition and distribution patterns, as
43 well as sources and pathways (Addamo et al., 2017; European Commission, 2018a; 2018b). A guidance
44 document produced by the MSFD Technical Group on Marine Litter (MSFD TG-ML) suggested five comparts
45 for monitoring marine litter in European Seas, i.e., beach litter, sea floor litter, floating litter, litter in biota
46 and micro-litter (MSFD GES Technical Subgroup on Marine Litter, 2013). Of these, MBL was expected to be
47 the most mature indicator and the one for which the most data could be easily available (Van Acoleyen et
48 al., 2013). The Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast
49 (IMAP), adopted by all Mediterranean countries in 2016, also includes indicator 22, which deals with litter
50 deposited on the coastline (UNEP/MAP, 2016).

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56 Even though it is more representative of land-based sources than that which is deposited far offshore, and
57 the ratio between sea-based and land-based sources may vary considerably between the regional seas, MBL
58 accumulation may be easier monitored and estimated than along water column or onto seabed (Schneider
59 et al., 2018). Generally, MBL monitoring constitutes a cost-effective methodology and its results can be
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1 considered somewhat representative of new litter entering the coastal environment. In particular, this is true
2 for urban beaches and those geographically under the influence of specific activities and discharges (Van
3 Acoleyen et al., 2013). Moreover, information on the temporal and spatial distribution of marine litter found
4 stranded on beaches can be effectively provided by non-government organizations (NGOs) and participatory
5 science campaigns (UNEP/MAP, 2015; Hidalgo-Ruz and Thiel, 2015) that also encourage communities to take
6 up actions toward responsible behaviours and fill in the knowledge gaps (Figueiredo Nascimento et al., 2016;
7 Hanke et al., 2019; Vlachogianni et al., 2020).

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10 Nevertheless, the increasing efforts to survey offshore areas aimed to improve the knowledge of marine litter
11 dispersal, concentration and type (e.g., MedSeaLitter EU Project, 2019), have not been always accompanied
12 in the Mediterranean by an equally increasing interest in the homogenization of the protocols and
13 methodologies devoted to the collection of reliable, coherent and comparable data of the composition and
14 distribution of MBL (Merlino et al., 2020). The number of MBL studies published to-date in peer-review
15 journals remains limited and often dedicated to specific coastal areas (Vlachogianni et al., 2020). Additionally,
16 these studies are generally characterized by differences in timing and frequency of the surveys, as well as by
17 discrepancies in litter sampling and classification, data analysis and waste disposal (e.g., Galgani et al., 2013;
18 Wenneker and Oosterbaan, 2010; Papachristopoulou et al., 2020; Grelaud and Ziveri, 2020; Vlachogianni et
19 al., 2020; Fortibuoni et al., 2021; Simon-Sanchez et al., 2022). It is extremely difficult to understand to what
20 extent the data produced are comparable or limited by the different methods.

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22 In this context, the present study reviews current literature relating to the monitoring and collection of MBL
23 over the Mediterranean coasts through bibliometric and content analyses, in order to compile information
24 about the applied monitoring strategies. Data collection takes advantage of the Scopus scientific database.
25 Based on this dataset, the discrepancies and similarities in the methods are analysed to identify where
26 current gaps lie and to point out what would be needed to progress in developing a basin-scale efficient
27 monitoring for the Mediterranean Sea. Moreover, we reaffirm the necessity of improving international
28 collaboration between Mediterranean countries, including the harmonization of directives and protocols
29 between European and North African countries, to provide a complete picture of the MBL pollution status in
30 this basin.

31 32 33 34 35 36 37 38 39 **2. Methods**

40 **2.1 Literature search**

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42 A systematic literature review was conducted to compile the MBL studies along the Mediterranean Sea coasts
43 and the associated monitoring strategies. In the first step, the Scopus, Elsevier scientific database
44 (www.scopus.com) was consulted, integrating logical operators, through specific string search. The search
45 was limited to English peer-reviewed articles published before 31st December, 2021.

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48 Taking advantage of the information about MBL queries provided by the same authors in Cesarano et al.
49 (2021), the search string was set to << beach* AND (marine OR coast*) AND (litter OR debris OR waste OR
50 *plastic) >>, in conjunction with << Mediterranean >> and the main regional terms referring to its main sub-
51 basins, in the "Article title", "Abstract" or "Keywords". This query resulted in 255 documents published
52 between 1978 and 2021 (see details in Supplemental material, Table S1). This dataset was exported as .csv
53 file including all the information provided by Scopus, i.e., "Citation Information", "Bibliographic Information",
54 "Abstract", "Keywords" and "References". To refine this dataset, the documents were further screened by
55 reading the titles and abstracts followed by the exclusion of those that were irrelevant to the objective of
56 this study (Afghan et al., 2020). In the third and last step, the documents were thoroughly screened (i.e.,
57 through full-text reading) to identify those eligible for the present analysis. The meeting criteria for inclusion
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in the following content analysis (see Section 2.2) was that the study must be addressing the data collection and/or analysis of macro-MBL (i.e., items ≥ 0.5 cm) over the Mediterranean shoreline, and providing details about the protocols and the methodologies applied. According to these criteria, the documents relating exclusively to micro-MBL were excluded at this stage. A stepwise sketch of the searching strategy is given as Figure 1.

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| 1 | Literature search <i>TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (mediterranean OR tyrrhenian OR balearic OR aegean OR adriatic OR ionian OR levantine OR alboran OR israel* OR ligur* OR tunisi* OR egypt* OR algerian))</i> Peer-reviewed articles before 31 st December 2021 | Documents 255 |
| 2 | Title and abstract screening | Documents 255 Out of scope - 105 |
| 3 | Full text review | Documents 150 Excluded - 92 |
| 4 | Content analysis | Documents 58 |

Fig. 1. Flow diagram illustrating the selection process and systematic review of the published literature.

2.2 Content analysis

After the full-text review, a content analysis was carried out extracting from each included study, and bringing together, information about the surveyed area, the sampling timing and the applied methodologies. In particular, the data concern: the locations, dates and frequency of the monitoring campaign; the number and characteristics (i.e., coastal type and beach typology) of surveyed sites; the description of the applied protocols and classification strategy (e.g., sampling unit and methodology, macro-litter definition size, number of examined categories); the total surveyed area and the total number/weight of the collected items; the performed statistical analysis.

This analysis provides a fairly comprehensive overview of the strategies adopted for monitoring macro-MBL along the Mediterranean coast as reported in Scopus indexed scientific articles, the occurrence of the sampling activities and the identification of the most (and least) investigated areas.

3. Results

3.1. Bibliometric research and data collection

The bibliometric analysis started with title and abstract screening of the selected articles (i.e., step 2 in Figure 1). Among them, 105 documents were discarded because out of the scope of this review since they were related to different environmental compartments (i.e., water surface, seafloor, sediment, biota), study areas (e.g., Atlantic Ocean), or disciplines (see details in Table S2). The full text review (i.e., step 3 in Figure 1) further reduced the eligible documents to 58 articles that were included in the following bibliometric and content analyses. Tables are presented in the following sections bringing together data from these

publications, specifying the locations, dates, frequency, and main sampling details of each survey (see Tables 1 to 3).

3.2. Temporal analysis

The bibliometric analysis draws data from 58 documents published between 1991 and 2021 (Table 1). The leading journal is *Marine Pollution Bulletin* that hosted about 42% of the Scopus indexed publications on the Mediterranean macro-MBL data monitoring activities. The temporal distribution of these documents indicates a consistent increase of the interest in this topic over the last decade (Figure 2). After a few pioneering studies focused on pellets, dated to late 70s and 80s (Shiber, 1979; 1982; 1987), the first articles on this topic appeared in the early 90s (e.g., Shiber and Barrales-Rienda, 1991; Gabrielides et al., 1991; Golik and Gertner, 1992). Nonetheless, the research interest in macro-MBL over the Mediterranean coasts was extremely modest during the 90s (Bowman et al., 1998) and 2000s (Tudor et al., 2002; Martinez-Ribes et al., 2007) and mostly devoted to specific regions (e.g., Israeli and Spanish beaches). The number of available scientific studies began to grow substantially since 2013 and continued to increase considerably through 2021. This is possibly a response to the overall rise of awareness towards the problem following the long-term accumulation of litter in the ocean and along the shoreline (Petry and Benemann, 2017; Schneider et al., 2018), and to the release of the MSFD guidance on monitoring of marine litter in European seas (Galgani et al., 2013). For example, the high number of studies published in 2021 (Figure 2) sum up the sampling efforts of the previous years when several projects were carried out in the framework of the Marine Strategy activities 2015-2020.

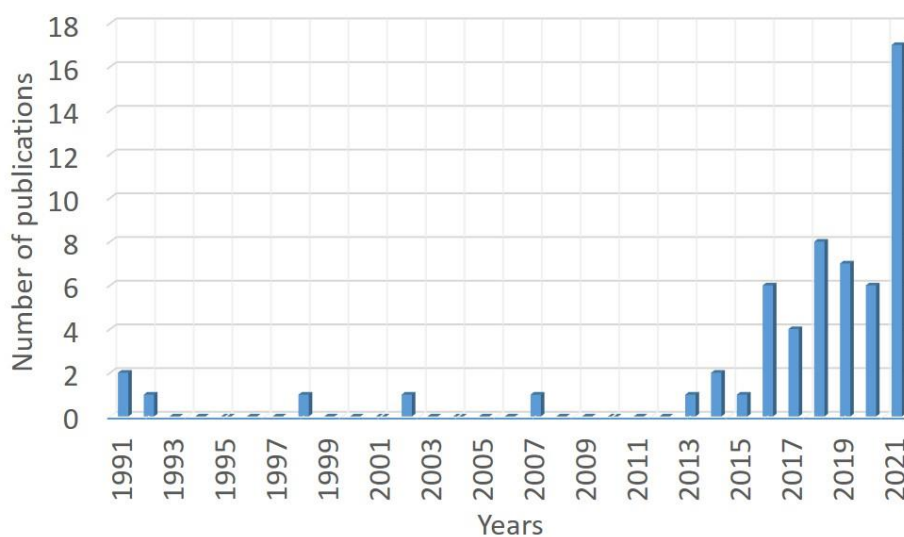


Fig. 2. Number of publications indexed in Scopus per year (1991–2021) dealing with macro-MBL monitoring.

A deeper analysis of the information reported in the selected publications shows that MBL scientific collection projects are typically conducted over a limited and short period of time covering two years or less (Table 1). The majority were collection activities and/or experiments that were started and completed within the same year. Actually, a third of the publications (19 of 58) reports about single-day surveys. Only 9 publications deal with macro-MBL monitoring activities characterized by a seasonal revisit time, as advised by international methodological indications (e.g., UNEP/MAP, 2016). A similar fraction, indeed, opted for monthly repetitions, while three monitoring projects were performed on a 15-days basis but over a shorter time period (i.e., four months). Other research activities are organized following different temporal strategies according to specific criteria, for example to have an overview of marine debris characteristics and

distribution before/after the touristic season (e.g., Grelaud and Ziveri, 2020), the periods in which beach cleaning operations are (are not) carried out (e.g., Nachite et al., 2019), or the realization of citizen awareness programmes.

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Table 1. Extracted temporal and geographical data from enquired Scopus indexed scientific surveys. Countries are reported through the ISO 3166-1 alpha2 code. Sites located in protected areas are indicated in cyano. Colours identify publications reporting information about beach typology (blue), coastal types (green) or both (red). Sites located in protected areas are indicated in blue (additional details in Table S3).

| ID | Reference | Time period | Frequence and timing | Number of sites | Location | Country | Journal |
|----|--|-------------|--|-----------------|--------------------------------------|--------------------|--|
| 1 | Shiber and Barrales-Rienda, 1991 | 1978 - 1978 | Twice per week (Jul) | 5 | Beirut | LB | Environmental Pollution |
| 2 | Shiber and Barrales-Rienda, 1991 | 1988 - 1988 | Three times (Mar, Apr) | 3 | Beirut | LB | Environmental Pollution |
| 3 | Golik and Gertner, 1992 | 1988 - 1989 | Monthly (May - May) | 6 | Israeli coast | IL | Marine Environmental Research |
| 4 | Gabrielides et al., 1991 | 1988 - 1989 | Monthly (May - May) | 13 | Spain, Italy, Turkey, Cyprus, Israel | ES, IT, TR, CY, IL | Marine Pollution Bulletin |
| 5 | Bowman et al., 1998 | 1990 - 1991 | Monthly (Jul - Oct) | 6 | Israeli coast | IL | Journal of Coastal Research |
| 6 | Tudor et al., 2002 | 1998 - 2000 | Single/multiple surveys per beach site | 7 | Turkey, Malta, Spain, Tunisia | TR, ES, MT, TN | Journal of Coastal Research |
| 7 | Martinez-Ribes et al., 2007 | 2005 - 2005 | Monthly (Apr, Jun - Sep) | 32 | Balearic Islands | ES | Scientia Marina |
| 8 | Kordella et al., 2013 | 2006 - 2007 | Once | 80 | Greece | GR | Aquatic Ecosystem Health and Management |
| 9 | Poeta et al., 2014; Poeta et al., 2016a | 2012 - 2012 | Once (Apr, May) | 5 | Lazio coast | IT | Marine Pollution Bulletin; Estuarine, Coastal and Shelf Science |
| 10 | Laglbauer et al., 2014 | 2012 - 2012 | Once (Jul) | 6 | Slovenia | SI | Marine Pollution Bulletin |
| 11 | Pasternak et al., 2017 | 2012 - 2015 | 14 to 19 surveys per beach site | 8 | Israeli coast | IL | Marine Pollution Bulletin |
| 12 | Gonulal et al., 2016 | 2013 - 2015 | Once | 14 | Gokceada Island | TR | Aquatic Ecosystem Health and Management |
| 13 | Camedda et al., 2021 | 2013 - 2016 | Twice a year (autumn, spring) | 7 | Sardinia | IT | Water Air and Soil Pollution |
| 14 | Karkanorachaki et al., 2018 | 2014 - 2014 | Summer (Apr - Jun), winter (Nov - Mar) | 4 | Northern Crete | GR | Marine Pollution Bulletin |
| 15 | Aydin et al., 2016 | 2014 - 2014 | Once (Apr) | 13 | Cilician Basin | TR | Turkish Journal of Fisheries and Aquatic Sciences |
| 16 | de Francesco et al., 2018 | 2014 - 2015 | Spring | 3 | Abruzzo e Molise | IT | Rendiconti Lincei. Scienze Fisiche e Naturali |
| 17 | Prevenios et al., 2018 | 2014 - 2015 | Every ~15 days (Jul - Oct) | 4 | Corfu Island | GR | Marine Pollution Bulletin |
| 18 | Poeta et al., 2016b | 2014 - 2015 | Spring, summer, autumn, winter | 3 | Montalto Marina | IT | Marine Pollution Bulletin |
| 19 | Giovacchini et al., 2018 | 2014 - 2015 | Spring, summer, autumn, winter | 11 | Pelagos sanctuary (Ligurian Sea) | IT | Marine Pollution Bulletin |

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| 20 | Vlachogianni et al., 2018 | 2014 - 2016 | Autumn, winter, spring, summer | 31 | Adriatic Sea | AL, BA, HR, GR, IT, MO, SL | Marine Pollution Bulletin |
| 21 | Alshawafi et al., 2017 | 2015 - 2015 | Spring, summer, autumn, winter | 1 | Martil | MA | Marine Pollution Bulletin |
| 22 | Maziane et al., 2018 | 2015 - 2015 | Once (Nov - Dec) | 14 | Mediterranean coast of Morocco | MA | Marine Pollution Bulletin |
| 23 | Munari et al., 2016 | 2015 - 2015 | Once (May - Jun) | 5 | North-western Adriatic coast | IT | Waste Management |
| 24 | Munari et al., 2017 | 2015 - 2015 | Once (May) | 5 | North-western Adriatic coast | IT | Waste Management |
| 25 | Nachite et al., 2019 | 2015 - 2017 | Twice a year (autumn, spring) | 14 | Alboran Sea | MA | Ocean and Coastal Management |
| 26 | Fortibuoni et al., 2021 | 2015 - 2017 | Twice a year (spring, autumn) | 64 | Italy | IT | Environmental Pollution |
| 27 | Portman and Brennan, 2017 | 2016 - 2016 | Every ~15 days (Apr - Jul) | 3 | Jisr-Az-Zarqa | IL | Waste Management |
| 28 | Loizidou et al., 2018 | 2016 - 2017 | Once (May - Aug) | 9 | Island of Cyprus | CY | Environmental Monitoring and Assessment |
| 29 | Papachristopoulou et al., 2020 | 2017 - 2018 | Summer, autumn, winter, spring | 62 | Western Saronikos Gulf | GR | Marine Pollution Bulletin |
| 30 | Ozden et al., 2021 | 2017 - 2019 | Monthly (Jan - Jan) | 8 | Northern Cyprus | CY | Marine Pollution Bulletin |
| 31 | Grelaud and Ziveri, 2020 | 2017 - 2019 | Monthly (Feb - Nov 2017, Aug - Sep 2019) | 35 | Mallorca, Sicily, Rab, Malta, Crete, Cyprus, Mykonos, Rhodes, | ES, IT, HR, MT, GR, CY | Scientific Reports |
| 32 | Silc et al., 2018 | 2017 -2017 | Once (May) | 1 | Velika plaža | ME | Marine Pollution Bulletin |
| 33 | Taibi et al., 2021 | 2017 -2017 | 10 - 21 replicates per beach site (Feb - Jul) | 9 | Western Algerian coast | DZ | Marine Pollution Bulletin |
| 34 | Gundogdu and Cevik, 2019 | 2018 - 2018 | Once (May) | 13 | Iskenderun Bay | TR | Environmental Pollution |
| 35 | de Francesco et al., 2019 | 2018 - 2018 | Once (Apr – May) | 7 | Abruzzo e Molise | IT | Sustainability |
| 36 | Gjyli et al., 2020 | 2018 - 2018 | Once (Apr) | 5 | Albanian coastline | AL | Ocean and Coastal Management |
| 37 | Asensio-Montesinos et al., 2019a | 2018 - 2018 | Once (Mar) | 56 | Alicante coast | ES | Marine Pollution Bulletin |
| 38 | Asensio-Montesinos et al., 2019b | 2018 - 2018 | Twice (Mar, Aug) | 56 | Alicante coast | ES | Ocean and Coastal Management |
| 39 | Mokos et al., 2019 | 2018 - 2018 | Once (Mar - May) | 3 | Croatian Adriatic Sea | HR | Rendiconti Lincei. Scienze Fisiche e Naturali |
| 40 | Vlachogianni et al., 2020 | 2018 - 2018 | Twice (autumn, winter) | 23 | Croatia, Cyprus, France, Greece, Italy | HR, CY, FR, GR, IT | Science of the Total Environment |
| 41 | Mo et al., 2021 | 2018 - 2018 | Twice (spring, autumn) | 3 | Ligurian Sea, Tuscany | IT | Marine Pollution Bulletin |
| 42 | Battisti et al., 2019 | 2018 - 2018 | Once (Mar) | 1 | Torre Flavia wetland | IT | Environmental Science and Pollution Research |

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| 43 | Mandic et al., 2021 | 2018 - 2019 | Three times (autumn, winter, spring) | 2 | Montenegrin coast | MO | The Montenegrin Adriatic Coast: Marine Chemistry Pollution |
| 44 | Mokos et al., 2020 | 2018 - 2019 | Summer, autumn, winter, spring | 1 | Vodenjak cove | HR | Rendiconti Lincei. Scienze Fisiche e Naturali |
| 45 | Bozzeda et al., 2021 | 2019 - 2019 | Once (Apr) | 1 | Aquatina | IT | Marine Pollution Bulletin |
| 46 | Asensio-Montesinos et al., 2021a | 2019 - 2019 | Monthly (Feb - Apr) | 12 | Ceuta | ES | Water MDPI |
| 47 | Romiti et al., 2021 | 2019 - 2019 | Monthly (Apr - Jun) | 2 | Ionian coast of the Calabria | IT | Journal of Insect Conservation |
| 48 | Fanini and Guittard, 2021 | 2019 - 2019 | Weekly (Apr - Sep), twice (Nov - Dec) | 2 | Island of Crete | GR | Marine Pollution Bulletin |
| 49 | Mghili et al., 2020 | 2019 - 2019 | Winter, spring, summer, autumn | 5 | Mediterranean coast of Morocco | MA | Marine Pollution Bulletin |
| 50 | Cesarini et al., 2021 | 2019 - 2019 | Once (Nov) | 1 | Torre Flavia wetland | IT | Marine Pollution Bulletin |
| 51 | Benaissa et al., 2021 | 2019 - 2019 | Once (Mar - Apr) | 10 | Aïn el Turk Bay | DZ | Geo-Eco-Marina |
| 52 | Ertas, 2021b | 2019 - 2020 | Summer, autumn, winter, spring | 1 | Adana Akyatan Lagoon Coast | TR | Marine Pollution Bulletin |
| 53 | Ertas, 2021a | 2019 - 2020 | Winter, spring, summer, autumn | 1 | Homa Lagoon coast | TR | Estuarine, Coastal and Shelf Science |
| 54 | Asensio-Montesinos et al., 2021b | 2020 - 2021 | Every ~15 days (Dec - Mar) | 5 | Alicante province | ES | Marine Pollution Bulletin |
| 55 | Cresta and Battisti, 2021 | 2021 - 2021 | Twice (Apr, May) | 1 | Torre Flavia wetland | IT | Marine Pollution Bulletin |
| 56 | Merlino et al., 2021 | 2021 - 2021 | Once (May) | 1 | Migliarino, Massacciucoli and San Rossore park | IT | Water |
| 57 | Katsanevakis, 2015 | NA | NA | 2 | Lesvos Island | GR | Mediterranean Marine Science |
| 58 | Battisti et al., 2016 | NA | NA | 1 | Torre Flavia wetland | IT | Environmental Practice |

3.3. Beach distribution and typology

At present there is no agreed statistical method for recommending a minimum number of sites that may be representative for a certain length of coast. This depends greatly on the purpose of the monitoring, on the geomorphology of the coast and how many sites that meet the sampling criteria are available (Galgani et al., 2013).

Figure 3 positions the reviewed macro-MBL collections. Generally, scientific efforts tend to focus on the European Mediterranean Sea. Information about the African coasts are largely missing, with the exception of Morocco (e.g., Maziane et al., 2018; Nachite et al., 2019; Mghili et al., 2020) and Algeria (Benaissa et al., 2021). Additional investigation is needed to determine whether those areas have been surveyed but not reported in scientific publications. Italy and Greece undertake major efforts, but also Israel, Cyprus and the Balkan countries are largely represented (Table 1). Consequently, Tyrrhenian, Adriatic and Aegean coasts are the most surveyed among the Mediterranean sub-basins (Figure 3). Conversely, several monitoring activities promoted by France, Spain and Turkey, which actually cover a larger fraction of their long coastline, are missing in scientific literature and do not appear in this bibliometric research.



Fig. 3. Geographical distribution of macro-MBL collections in the Mediterranean Sea and its main sub-basins. Yellow dots indicate the beaches where single or multiple surveys were realized.

The amount and the composition of MBL can vary over geographical scales and reflects the geomorphological and hydrographical characteristics of the coast (Ansari and Farzadkia, 2022). Different criteria drive the selection of the surveyed areas according to the objectives of each monitoring campaign. The majority of the analysed projects consider specific factors and often aim at covering different exposure to natural and anthropogenic drivers of litter deposition (e.g., Prevenios et al., 2018). Among these factors, the most represented are i) distance from urban areas, harbour, river outflow, shipping lane; ii) prevailing meteorological conditions (e.g., sea currents and winds); iii) beach characteristics (e.g., length, orientation, substrate and slope); iv) usage of the beach and/or of the surrounding area (e.g., tourism, agriculture, industrial activities). Sometimes, surveyed areas distribution is arbitrarily selected to uniformly cover the whole length of an investigated coastline (e.g., Asensio-Montesinos et al., 2019a). Only a few studies (17%)

1 focus on natural reserves and marine protected areas (e.g., Giovacchini et al., 2018; de Francesco et al.,
2 2021). This is possibly due to the MSFD and UNEP guidelines suggesting that survey activities should be
3 conducted so as not to impact on any endangered or protected species (Cheshire et al., 2009; Galgani et al.,
4 2013).

5 Beach typology information is provided in 59% of the publications (Table 1 and Table S3). Nevertheless, only
6 one third of the publications follow the Bathing Area Registration and Evaluation (BARE) system (see chapter
7 9 in Williams and Micallef, 2009) that classifies coastal sites into four beach types (remote, rural, village,
8 urban), according to the difficulty of access, level of coastal occupation and community services. Thus, criteria
9 are not completely homogenous. Several authors, in fact, only indicate the main destination of the area, e.g.,
10 touristic/non-touristic (Lagalbauer et al., 2014); very touristic/low touristic/remote (Grelaud and Ziveri,
11 2020); industrial/agricultural/urban/rural (Gundogdu and Cevik, 2019); or its geographical characteristics,
12 such as wetland (Alshawafi et al., 2017; Battisti et al., 2019), river estuary (e.g., Romiti et al., 2021). As stated
13 above, a few publications report more detailed information about beach selection, including parameters such
14 as minimum length or width, slope range, access, presence of vegetation, dunes, road, fence or other
15 anthropogenic structures (e.g., Vlachogianni et al., 2020).

16 As for shoreline characteristics, 78% of analysed papers report information about the coastal type (see Table
17 1 and Table S3). As expected, sandy beaches represent the majority of the surveyed sites. However, rocky
18 areas, cobbles and pebbles beaches, and less frequently cliffs and artificial coasts, have been also studied.

25 3.4. Sampling methodologies and data analysis

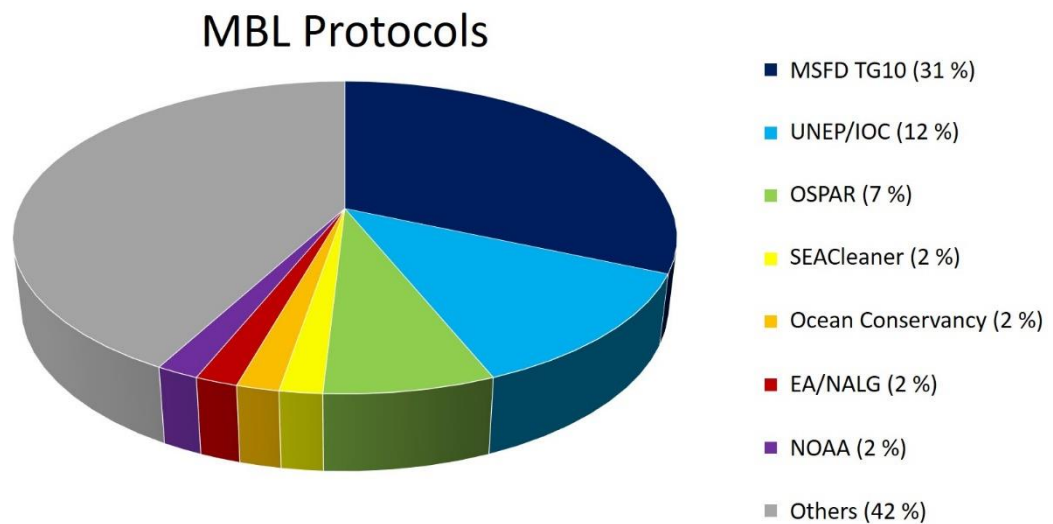
26 Depending on how they are designed and realized, MBL counts and collections can reflect the presence,
27 amounts and types of marine debris, and the long-term balance between inputs (e.g., land-based sources,
28 storms, tides) and export (e.g., degradation, clean-up) over a coastal area (Portman and Brennan, 2017).
29 However, the evaluation of fluxes between beaches and nearshore marine waters is usually difficult. Surveys
30 mostly represent a valid tool for tracking minor changes in overall abundance and accumulation rates, as well
31 as for monitoring evident changes in the composition of litter (Galgani et al., 2013). These goals imply an
32 appropriate logical temporal and spatial organization of surveys and the choice of criteria (e.g., parameters,
33 standard sampling units, replications) that allow the inter-comparison between observations collected by
34 different operators in different moments over the same (or different) areas.

35 The sampling strategies to assess the occurrence of MBL include a wide range of methodologies/approaches,
36 depending on many factors, including the main goal of a given study (Velander and Mocogni, 1999; Romiti et
37 al., 2021) and the costs associated to the application of different protocols. The latter include, for example,
38 labour in different phases of monitoring, equipment, specialized personnel and other running costs (MSFD,
39 2013).

40 Table 2 summarizes surveys information for scientific collections analysed in this study. The compiled
41 information shows a large variety of applied methodologies and criteria. Firstly, the standard unit (i.e., the
42 fixed section (length) of beach from which measurements of litter number of items, weight or volume are
43 made periodically - Galgani et al., 2013), is usually very different among the collections. Only for half of them
44 (29 of 58) it consisted of a 100 m long coastal sector. Some authors opted for 50 m or for full length of the
45 surveyed beach (about 18%). Other sampling activities (20%), indeed, opted for quadrats instead of linear
46 transects. Again, quadrats dimensions vary from site to site (Table 2). The remaining publications present
47 customized sampling units due to specific research interests or to the absence of standardized protocols (e.g.,
48 for studies dating to the '80s). The different strategies, of course, imply manual collections of litter items
49 during some surveys (about 80 %), and only visual inspection during others (about 20%). In some cases (20%)
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1 the observer recorded litter data whilst moving along separated transects parallel to the coastline (usually 5
2 m wide) in order to cover the entire usable beach, from the shoreline up to its landward limits (e.g., Asensios
3 Monteisons, 2019a). Conversely, 30% of the surveys were performed along transects normal to the coastline,
4 from the strandline to the back of the beach (e.g., Grelaud and Ziveri, 2020).

5 Another important difference lies in the size of MBL surveyed during monitoring activities. Different
6 definitions can be found in the analysed publications. Generally, there are no upper size limits and classes of
7 items. On the other hand, the lower limit of detection varies considerably from survey to survey. A few
8 collections (10%) set the MBL size lower limit at 0.5 cm (e.g., Taibi et al., 2021). As generally recommended,
9 most of the analysed collections (41%) opt indeed for a lower limit of 2.5 cm in the longest dimension (e.g.,
10 Giovacchini et al., 2018). This ensures, for example, the inclusion of caps and lids and cigarette butts in any
11 counts (Galgani et al., 2013). Other surveys use different lower limits (28%), such as 2 cm (12%) or 1 cm (5%),
12 or do not provide clear information about size limits (21%).



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Fig. 4. Percentage distribution of sampling protocols used in MBL data collections indexed in Scopus.

40 All these differences are the results of the application of different protocols providing specific guidelines for
41 MBL sampling. Figure 4 summarizes information reported in Table 2 through the percentage distribution of
42 the official protocols applied in the analysed studies. Since their release in 2013, the guidelines suggested by
43 the MSFD technical group on marine litter (MSFD Technical Support group on marine litter, 2013) represent
44 the most used protocol (31%). These recommendations are based on the OSPAR Commission Guidelines for
45 Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (OSPAR, 2010a), UNEP Operational
46 Guidelines for Comprehensive Beach Litter Assessment (Cheshire et al., 2009) and the NOAA Marine Debris
47 Shoreline Survey Field Guide (Opfer et al., 2012).

48 Similar differences can be found in the existing approaches for identification and classification of information
49 about the observed MBL typology. Most of the analysed studies firstly group MBL items into macro-
50 categories according to the basic material they are made of (e.g., plastics, wood, metal, glass, paper, organic
51 matter, etc.), then divide them into specific typologies. Although several detailed international guidelines
52 exist (e.g., EA/NALG, 2000; Cheshire et al., 2009; OSPAR, 2010a; Opfer et al., 2012; Galgani et al., 2013),
53 scientists are often dealing with specific interests and needs, so they categorize litter into personalized
54 groups (e.g., Battisti et al., 2019; Fanini and Guittard, 2021) or combine different litter classification schemes
55 (Asensio-Montesinos et al., 2021a). Sometimes, very detailed information, such as the specific type or even
56 brand of single items, are also used to support specific analyses, such as source attribution (e.g., Golik and
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1 Gertner, 1992; Renzi and Blaskovic, 2018). Among the selected publications, the most used classification
2 scheme (31%) is the master list suggested by MSFD GES Technical Subgroup on Marine Litter (Galgani et al.,
3 2013). This reference list was developed as part of a technical (non-legally binding) guidance document with
4 recommendations for monitoring marine litter in accordance with the MSFD (Portmann and Brennan, 2017).
5 It considers 213 categories referring to MBL grouped into eight material classes and permits to assign each
6 litter item to a standard General Code (G-Code). However, several studies that use G-code only consider a
7 subset of 165 relevant categories, among the 213 available for MBL classification, excluding categories for
8 micro-litter (i.e., G103-123) or other residual types of items which are not applicable to monitoring marine
9 macro-litter on beaches. G-code was derived in order to move towards harmonised monitoring, but different
10 lists have been and are still being used in parallel, such as the OSPAR Items List for 100-metre sampling, which
11 contains 121 MBL categories divided into 11 groups of classes, or the UNEP/IOC items list, which includes 77
12 typologies grouped in 10 material classes.
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15 Furthermore, different studies count and report MBL amount in different ways. The unit in which litter is
16 assessed range among number, weight or volume. A combination of these units can be also used (see Table
17 3). Generally, count of items is recommended as the easiest way to assess its presence along the coastline.
18 The assessment of weight of litter, instead, can be more difficult because it is dependent on MBL items
19 conditions (e.g., wet or dry, covered or plenty of sand or gravel, too big for being weighted on site; Jambeck
20 and Farfour 2011). The assessment of the volume of litter is also problematical because it depends on the
21 level of compression of the litter involved. Among the analysed collections, just two studies do not consider
22 items abundance preferring to assess MBL through its weight (Alshawafi et al., 2017) and percentage
23 coverage (Mo et al., 2021). Conversely, 33 studies report only MBL abundance, while the others focus on
24 abundance and weight or a combination of different parameters including abundance (19 and 5 documents,
25 respectively). It is also interesting to notice that 19% of the available documents do not mention if/how MBL
26 was removed during/after beach surveys, or they adopt methodologies that include visual census without
27 waste removal (Merlino et al., 2021). Moreover, only six studies declare a direct participation of volunteers.
28 However, as stated above, non-scientific initiatives usually have no fixed end-date and are characterized by
29 a massive use of websites and outreach reports, thus appearing in scientific publications only at later stages,
30 frequently after several years, when scientific conclusions can be finally retrieved (Schneider et al., 2018).
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33 Whatever is the applied collection methodology, scientists usually convert their abundance, weight or
34 volume information into density, opting for per beach length unit (m) rather than per beach area unit (m²) in
35 order to facilitate the comparability of MBL on a temporal, local, or global level (Papachristopoulou et al.,
36 2020). Still, differences exist among available studies estimating density per m (m²) or 100 m (100 m²) of
37 beach face length (Table 3). Most of the analysed studies reporting MBL abundance densities express them
38 in items/m² or items/100 m² (66%), while a lower percentage of collections use per length units (21%) or both
39 (13%). Statistical analyses are always very useful when processing and interpreting these data. Table 3 shows
40 that a variety of univariate and multivariate analyses have been used in the selected publications. Opting for
41 a specific statistical tool seems to be generally driven by the research objectives more than the typology of
42 the collected dataset. Mathematical formulas and coefficients can be used for providing an evaluation of
43 beach quality, for example through common shared indices, and litter sources. The clean cost index, for
44 example, provides an aggregate indicator that translates the quality of the beaches in terms of potential and
45 direct damage to the health of marine organisms, and it results very useful for spatial (e.g., beaches with
46 different characteristics) and temporal (e.g., seasonal or interannual) comparisons. Nevertheless, only 34%
47 of the analysed studies reports this kind of information using different indices, i.e., clean cost index (15
48 studies), litter grade (3), pollution density index (1), index of environmental spoil (1), accumulation index (1),
49 Chao's Sørensen index (1).
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Finally, it is noteworthy that 81% of available Scopus indexed documents deal, somehow, with litter source analysis. To this goal, a variety of methods have been used, from simple counts of items believed to originate from a given source to more complex mathematical methods, such as the Matrix Scoring Technique proposed by Tudor and Williams (2004) and further developed by ARCADIS (Van Acoleyen et al., 2013) for use with the OSPAR MBL data. This technique considers the level of likelihood of the origin of each litter item evaluating all potential sources. A qualitative score (e.g., from "very likely" to "very unlikely" or "not considered") is assigned to each potential source and then translated to a scoring system (i.e., using weighted numerical values). The attribution of likelihoods is based on the type of litter, distance from each source, impact of a specific activity in the area and any other local factor that can affect litter contribution (Veiga et al., 2016).

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Table 2. Surveys information for scientific collections identified by ID numbers, as in Table 1.

| ID | Sampling unit | Transect details | Units | Tot area or length | Methodology | MBL size | Protocol | MBL classification |
|----|----------------------|---|-------|------------------------|----------------------|----------|----------------------------------|---|
| 1 | customized | area included the zone between the low and high water marks | 7 | 1500 m ² | visually | > 2 cm | NA | type (e.g., metal, plastic, glass, paper) |
| 2 | customized | area included the zone between the low and high water marks | 1 | NA | manually | > 2 cm | NA | type (e.g., metal, plastic, glass, paper) |
| 3 | customized | 5 m wide, normal to the coastline, from the waterline to the back of the beach | 472 | NA | visually or manually | > 1 cm | NA | NA |
| 4 | customized | normal to the coastline, from the waterline to the back of the beach | 64 | NA | manually | > 2 cm | NA | 7 groups (plastics, wood, Styrofoam, fishing gear, glass, metal, other) |
| 5 | 50 m | | NA | NA | visually | NA | NA | 7 groups (plastic, metal, glass, paper, wood, cloth, other) |
| 6 | 100 m | | 15 | 1500 m | manually | NA | EA/NALG | 45 litter types |
| 7 | customized | 2 m wide, normal to the shoreline, 15 m apart, upper few cm | NA | NA | manually | > 0.1 cm | NA | 7 groups (plastics, wood, metal, glass, paper, organic matter, other) |
| 8 | full beach | | NA | NA | manually | ≥ 1 cm | NA | 8 groups (glass, plastic, paper, aluminum, other metals, rope, building materials, other materials) |
| 9 | 2 x 2 m ² | | 153 | 612 m ² | visually | > 2.5 cm | NA | 165 categories in 8 groups (G-code) |
| 10 | 50 m | parallel to the shoreline | 6 | 300 m | manually | ≥ 2 cm | UNEP/IOC (Cheshire et al., 2009) | 59 categories in 8 groups |
| 11 | 100 m | 12 m wide | 146 | 33,790 m ² | visually | NA | UNEP/IOC (Cheshire et al., 2009) | 87 categories |
| 12 | customized | normal to the coastline, from the action of waves limitation up to territorial plants | NA | 209,220 m ² | manually | > 2.5 cm | NA | 10 groups about material (plastic, nylon, fibres, polystyrene, glass, metal, paper, wood, synthetic material, cigarette butts/package) and 11 about usage (drink packaging, food packaging, |

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| | | | | | | | | packaging, fishing material, rope, recreational, cleaning supplies, medical supplies, cigarette, cloth/shoes, others) |
| 13 | 100 m | parallel to the shoreline | 3 | 300 m | manually | NA | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 14 | 0.4 x 0.4 m ² | 5 m apart, from the back of the beach to the waterline, 10 cm depth | 75 | 12 m ² | sieved by a 2mm mesh | > 2.5 cm | NA | 165 categories in 8 groups (G-code) |
| 15 | 100 m | | NA | NA | manually | > 2 cm | MSFD TG10 | 8 groups (cloth, foamed plastic, glass and ceramics, metal, paper and cardboard, plastic, rubber, wood) |
| 16 | customized | parallel to the coastline, from the shoreline to the dune habitats | NA | NA | manually | > 0.5 cm | OSPAR | 6 groups (plastic, polystyrene, glass, paper, mixed, other) |
| 17 | 100 m | perpendicular to the coastline, from waterline to the back of the beach | 144 | 595,200 m ² | manually | > 2.5 cm | MSFD TG10 | 213 categories in 8 groups (G-code) |
| 18 | 100 m | perpendicular to the coastline, from sea line to back dune's woody vegetation | 15 | 112,500 m ² | manually | > 2 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 19 | 100 m | perpendicular to the coastline, from waterline to the back of the beach | 33 | 32,154 m ² | manually | NA | SEACleaner Protocol | 33 categories in 9 groups (plastic, polystyrene, wood, foam/sponge, textiles, multimaterial, rubber, glass, metal) |
| 20 | 100 m | perpendicular to shoreline, 50 m apart | 180 | 33,200 m ² | manually | all items | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 21 | 100 m | | NA | NA | manually | > 2 cm | NOAA (Ioakeimidis et al., 2016) | 6 categories (plastic, lumber and paper, cloth and fabric, glass, metal, rubber) |
| 22 | 100 m | parallel to shoreline, 5 m apart between shoreline and beach landward | 17 | 108,051 m ² | manually | > 2.5 cm | UNEP/IOC (Cheshire et al., 2009) | 7 groups (artificial polymers, rubber, textile, paper, metal, wood, glass and ceramics) |
| 23 | 50 m | perpendicular to the beach, from waterline to the back of the beach | 10 | 12,000 m ² | manually | > 2.5 cm | UNEP/IOC (Cheshire et al., 2009) | 76 categories in 9 groups |
| 24 | 0.5 x 0.5 m ² | 10 m wide along shoreline | 30 | 7.5 m ² | manually | NA | NA | fragments, pellets, films |

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| 25 | 100 m | parallel to shoreline, 5 m apart from the strandline to the beach landward | 56 | 408,204 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 26 | 100 m | perpendicular to the coast, no more than 50 m apart | 192 | 19,200 m | manually | > 0.4 cm | MSFD TG10 | 59 categories in 10 groups |
| 27 | 100 m | | 21 | 5476 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 9 groups (G-code) |
| 28 | full beach | | NA | 20,980 m ² | manually | NA | Ocean Conservancy | 41 categories (Ocean Conservancy) |
| 29 | full beach | | NA | 31,461 m ² | vessel-based photography | ≥ 2.5 cm | MSFD TG10 | 213 categories in 8 groups (G-code) |
| 30 | 50 m | | 104 | 26,000 m ² | manually | > 2.5 cm | MSFD TG10 | 8 groups (OSPAR, 2010a) |
| 31 | 100 m | perpendicular to the beach, from waterline to the back of the beach | 147 | 14,700 m | manually | > 2.5 cm | OSPAR | 9 groups (artificial polymer materials, rubber, cloth/textile, paper/cardboard, processed/worked wood, metal, glass/ceramics, unidentified and chemicals) |
| 32 | 2 x 2 m ² | random quadrats | 120 | 480 m ² | manually | all items | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 33 | 0.5 x 0.5 m ² | perpendicular to the coastline, 20 m apart along highest waterline; 5 cm depth | 110 | 27.5 m ² | sieved by a 1mm mesh | ≥ 0.5 cm | NA | fragments, pellets, films |
| 34 | 1 x 1 m ² | high strandline, mid line, backshore line; 5 cm depth | 117 | 117 m ² | sieved by a 5 mm mesh | > 2.5 cm | adapted from Losh (2015), Frias et al. (2018) | 5 groups of plastics (filament, film, foam, fragments, pellets) |
| 35 | 2 x 2 m ² | random quadrats | 180 | 720 m ² | manually | > 2.5 cm | OSPAR, UNEP/MAP | 6 groups about material (plastic, polystyrene, glass, paper, aluminum, mixed waste) and 5 for usage (containers, fishing and boating, food and beverage, packaging, other) |
| 36 | 100 m | perpendicular to the coast, 50 m apart | 10 | 24,000 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 37 | 100 m | parallel to coastline, 5 m apart | NA | 201,686 m ² | visually | > 2.5 cm | UNEP/IOC, NOAA, OSPAR | 116 categories in 8 groups (UNEP code) |
| 38 | 100 m | parallel to coastline, 5 m apart | NA | 201,700 m ² | visually | > 2.5 cm | EA/NALG, UNEP/IOC, | 129 categories in 8 groups (UNEP code) |

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| | | | | | | | OSPAR, NOAA | |
| 39 | 100 m | 10 m wide along shoreline | 3 | 2800 m ² | manually | > 0.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 40 | 100 m | perpendicular to the coastline, at least 50 m apart | 62 | 113,780 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories (G-code) in 3 groups (single-use plastics, non-single use plastics, non-plastics) |
| 41 | 4 x 4 m ² | random quadrats, with nested 1 x 1 m ² plots | 22 | 352 m ² | visually | > 2.5 cm | NA | 213 categories in 8 groups (G-code) |
| 42 | full beach | | NA | 15,000 m ² | manually | > 3 cm | NA | fishing lines and hooks |
| 43 | 100 m | perpendicular to the coastline, from the strandline to the back of the beach | 18 | 16,500 m ² | manually | all items | MEDPOL | 11 categories (plastic, rubber, textile, glass, ceramics, processed wood, metal, paper, sanitary waste, medical waste, paraffin/wax) |
| 44 | 100 m | 10 m wide | 4 | 4000 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 45 | 0.3 x 0.3 m ² | random quadrats, from the shoreline to the base of the dune; 10 cm depth | 9 | 0.81 m ² | box corer | > 3 cm | allometric models | plastic items |
| 46 | 100 m | parallel to the shoreline, 5 m apart | NA | 63,645 m ² | visually | > 2.5 cm | UNEP/MAP | 207 categories in 9 groups (UNEP code) |
| 47 | full beach | wet beach, dry beach, fore dune, hind dune | NA | 48,000 m ² | manually | container | Poeta et al. 2015 | 3 groups (plastic, glass, aluminium) in 5 categories of shape/volume (small bottles (< 1.5 l), large bottles (≥ 1.5 l), tanks (≥ 5 l), jars (0.3-1 l), cans (0.3–0.5 l)) |
| 48 | 400 m | | NA | 400 m | manually | > 2.5 cm | NA | 2 groups (traws, wraps litter) |
| 49 | 100 m | 20 m wide | 19 | 38,000 m ² | manually | NA | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 50 | 0.2 x 0.2 m ² | parallel to the coastline, 30 m from the water's edge, 50 m apart | 32 | 1.28 m ² | manually | > 2.5 cm | customized | vegetal wrack and plastic litter (Hanke et al., 2013) |
| 51 | 100 m | parallel to shoreline, from the water line to the beach backshore | 10 | NA | manually | > 5.0 cm | UNEP/IOC (Cheshire et al., 2009) | 5 groups (bottles, bags, packaging, tyres, other) |
| 52 | 100 m | from the landward beach limit to the shoreline, garbage bins | 5 | 500 m | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |

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|----|----------------------|---|-----|-----------------------|-----------------------------------|----------|--------------------------|---|
| 53 | 100 m | from the landward beach limit to the shoreline, garbage bins | 8 | 800 m | Manually | > 0.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 54 | full beach | perpendicular to the coastline, 2 m apart from the strandline to the backshore area | 35 | 73,451 m ² | Manually | > 0.5 cm | Williams and Tudor, 2001 | 183 categories |
| 55 | 90 m | along the dunes, backdunes, channels in wetland | 13 | 1170 m | sieve by a 8 mm mesh | > 1 cm | customized | total litter and expanded polystyrene subcategory (EPS) |
| 56 | 3 x 3 m ² | | 100 | 900 m ² | unmanned aerial vehicle, visually | > 0.5 cm | OSPAR | 43 tipologies divided in 6 groups (fragments, containers, packaging, sanitary, clothing, others) |
| 57 | 100 m | perpendicular to the coastline, from the tide line to the back border of the beach | 2 | 1600 m ² | manually/visually | > 5 cm | NA | 28 categories |
| 58 | Customized | | NA | 3000 m ² | Manually | > 2.5 cm | NA | 7 groups (bottle cap, cotton buds, expanded polystyrene, cigarette butts, generic fragments, bottles, other containers) |

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Table 3. MBL collection details for surveys identified by ID numbers, as in Table 1.

| ID | Measurements | Total litter | Litter density estimation | litter removal | Volunteers participation | Statistical analysis | indices | Sources analysis |
|----|----------------------|--------------------------|--|----------------|--------------------------|--|---|------------------|
| 1 | abundance | | g cm ⁻³ | | | | | yes |
| 2 | abundance | | g cm ⁻³ | | | | | yes |
| 3 | abundance | 17,355 items | | yes | | Wilcoxon test, Duncan test | | yes |
| 4 | abundance and weight | | g m ⁻¹ | yes | | | | yes |
| 5 | abundance | | items 100 m ⁻² | | | | pollution density index, index of environmental spoil | |
| 6 | abundance | | | yes | | PCA, cluster analysis | | yes |
| 7 | abundance and weight | | items m ⁻¹ | yes | | PCA, multivariate analysis, redundancy analysis, univariate analysis of variance | | yes |
| 8 | abundance | 110,423 items | | yes | yes | R-mode factor analysis, cluster analysis | | yes |
| 9 | abundance | | | | | Shapiro–Wilk test, Kruskal–Wallis test, generalized linear mixed-effects model, Pearson correlation test | | yes |
| 10 | abundance and weight | 5,870 items | items m ⁻² g m ⁻² | yes | | multidimensional scaling | clean coast index | |
| 11 | abundance | 69,122 items | items 100 m ⁻² | yes | | | | yes |
| 12 | abundance | 1,445 items | items 100 m ⁻² | yes | | | | yes |
| 13 | abundance | 39,972 items | items 100 m ⁻¹ | yes | | PERMANOVA | | |
| 14 | abundance and weight | 12,263 items 0.734 kg | items m ⁻² g m ⁻² | yes | | | | |
| 15 | abundance and weight | | items m ⁻² g m ⁻² | yes | | multivariate adaptive regression splines | clean coast-index | yes |
| 16 | abundance | 6,100 items | | yes | | | | yes |
| 17 | abundance and weight | 41,617 items | items 100 m ⁻¹ items m ⁻² | yes | | PCA, Kruskal-Wallis test, Dunn's test, PCA with Varimax rotation, PERMANOVA, Kaiser-Meyer-Olkin test | | yes |
| 18 | abundance | 31,739 items | items m ⁻¹ | yes | | PERMANOVA, SIMPER | | yes |
| 19 | abundance | 34,027 items | items m ⁻² | yes | yes | PCA, cluster analysis | clean coast index | yes |

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|----|------------------------------|--------------------------|--|-----|-----|---|-----------------------|-----|
| 20 | abundance | 70,581 items | items 100 m ⁻¹ items m ⁻² | yes | | | clean coast index | yes |
| 21 | weight | 12.855 kg | | yes | yes | PCA, cluster analysis | | yes |
| 22 | abundance and weight | 8,021 items 198 kg | items m ⁻² g m ⁻² | yes | | | | yes |
| 23 | abundance | 2,502 items | items m ⁻² | yes | | PERMANOVA, regression analysis, Shannon's diversity index, UPGMA sorting, Bray-Curtis index, SIMPER | clean coast index | yes |
| 24 | abundance and weight | 1,345 items 13.491 kg | items m ⁻² items kg ⁻¹ | yes | | PERMANOVA, Bray-Curtis index, SIMPER | | |
| 25 | abundance | 21,943 items | items 100 m ⁻¹ items m ⁻² | yes | | | clean coast index | yes |
| 26 | abundance | | items 100 m ⁻¹ | yes | | PERMANOVA, SIMPER | | yes |
| 27 | abundance | 3,305 items | items m ⁻² | yes | | Pearson's Chi-Square test | clean coast index | |
| 28 | abundance | 7,658 items | | yes | yes | | | yes |
| 29 | abundance | 17,620 items | items 100 m ⁻¹ | | | regression analysis | | yes |
| 30 | abundance and weight | 59,556 items 697 kg | items m ⁻² items m ⁻¹ g m ⁻² g m ⁻¹ | yes | | | | yes |
| 31 | abundance | 162,320 items | items m ⁻² | yes | | accumulation rate | accumulation index | yes |
| 32 | abundance | 585 items | items m ⁻² | yes | | univariate statistics, SIMPER, PCA | | yes |
| 33 | abundance, weight, colour | 356 items | items m ⁻² g m ⁻² | yes | | Mann-Whitney test, Kruskal-Wallis test, NDWD test | | yes |
| 34 | abundance and weight | 1,424 items | items m ⁻² g m ⁻² | yes | | Mann-Whitney test, Kruskal-Wallis test, PERMANOVA, PCA, Bray-Curtis index | | yes |
| 35 | abundance | 1,492 items | items m ⁻² | yes | | PCA, Mann-Whitney test | | yes |
| 36 | abundance | 3,321 items | items 100 m ⁻¹ items m ⁻² | yes | | cluster analysis | | yes |
| 37 | abundance | 10,101 items | items m ⁻² | | | multivariate analysis, nMDS, cluster analysis | litter grade | yes |
| 38 | abundance | 30,941 items | items m ⁻² | | | nMDS, PCA, cluster analysis | litter grade | yes |
| 39 | abundance and weight | 6,010 items | items m ⁻² | yes | | | clean coast index | yes |

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| 40 | abundance | 37,991 items | items 100 m ⁻¹ items m ⁻² | yes | yes | cluster analysis | | yes |
| 41 | percentage coverage | | | | | Kruskal-Wallis test, PERMANOVA, diachronic analyses, Shapiro-Wilk test, Levene test | | |
| 42 | abundance, length of the lines, density of hooks | 243 fishing lines 88 skeins 33 hooks | cm m ⁻² mg m ⁻² items ha ⁻¹ | yes | | | | |
| 43 | abundance and weight | 133,4 kg | items m ⁻² | yes | | | clean coast index | |
| 44 | abundance | 11,024 items | items m ⁻² | yes | | | clean coast index | yes |
| 45 | abundance and weight | | | yes | | nMDS | | |
| 46 | abundance | 31,571 items | items 100 m ⁻¹ items m ⁻² | yes | | Kolmogorov–Smirnov test, Bartlett’s test, Tukey’s test, ANOVA | litter grade, clean coast index | yes |
| 47 | abundance | 2,177 containers | items 100 m ⁻² | | | | chao’s sørensen index | |
| 48 | abundance, shape, colour | | items m ⁻¹ | yes | | Spearman rank correlation | | yes |
| 49 | abundance and weight | 7,839 items 231 kg | items m ⁻² g m ⁻² | yes | | | clean coast index | yes |
| 50 | abundance and weight | | items m ⁻² | yes | | Mann-Whitney test, Pearson or Spearman correlation test | | |
| 51 | abundance | 14,537 items | items m ⁻² | yes | | | | yes |
| 52 | abundance and weight | 2,324 items 105.44 kg | items m ⁻² g m ⁻² | yes | | one-way ANOVA | clean coast index | yes |
| 53 | abundance and weight | 10,717 items 229.29 kg | items m ⁻² g m ⁻² | yes | | one-way ANOVA | clean coast index | yes |
| 54 | abundance | 2,410 items | items 100 m ⁻¹ items m ⁻² | yes | | nMDS, cluster analysis, Bray–Curtis index | clean coast index | yes |
| 55 | abundance | 2,120 items | | yes | | Kruskall-Wallis test, Mann-Whitney test | | |
| 56 | abundance and colour | 332 items | | | yes | Kendall’s coefficient of concordance | | yes |
| 57 | abundance and weight | 810 items 1641.25 kg | | | | | | yes |
| 58 | abundance and weight | 6,700 items, 10.717 kg | | yes | | | | |

4. Discussion

1 The assessment of litter composition is one of the great strengths of coastal monitoring. A detailed
2 assessment can provide information on potential harm to the environment and, potentially, on the source of
3 the litter found (Ansari and Farzadkia, 2022). To this aim, the assessment and analysis of MBL must follow
4 commonly agreed methodologies in order to provide results which are comparable over larger regions and
5 different periods.
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8 The Final Report “Guidance on Monitoring of Marine Litter in European Seas” (Galgani et al., 2013), realized
9 by MSFD TSG-ML, provides recommendations and information needed for an effective monitoring of the
10 MBL. Much of the information included is taken from some of the most comprehensive and useful overviews
11 for monitoring methods on the coast, i.e., the UNEP (Cheshire et al., 2009), the OSPAR (OSPAR, 2010a), and
12 the NOAA (Opfer et al., 2012) guidelines.
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15 MSFD TSG-ML suggests that when designing marine litter surveys, it is necessary to differentiate between
16 standing-stock surveys, where the total load of litter is assessed during a one-off count, and the assessment
17 of accumulation and loading rates during regularly repeated surveys of the same stretch of beach with initial
18 and subsequent removal of litter (Galgani et al., 2013). The amount of litter arriving on a given length of
19 beach over a given period of time can be expressed as [unit quantity of litter] per [unit length of beach] per
20 [unit time]. Conversely, the amount of material standing on the beach is usually determined as [unit quantity
21 of litter] per [unit length of beach] (Cheshire et al., 2009). The accumulation periods should be approximately
22 of the same length. To this aim, the minimum sampling frequency of a given beach should be annually,
23 roughly on the same day each year. Ideally, beach site should be surveyed every three months through
24 seasonal collections at regular intervals in time. Thus, at least four surveys per year (i.e., in spring, summer,
25 autumn and winter) are recommended by MSFD (Galgani et al., 2013).
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28 Nevertheless, the information reported in the analysed Scopus indexed publications shows that MBL
29 monitoring activities are typically conducted over a limited and short period of time (e.g., covering two years
30 or less, or even including only single-day surveys). This implies that only few studies can effectively assess
31 the temporal variation in the amount of litter present on a given beach, or several beaches. Additionally, also
32 the collections characterized by seasonal repetitions are significantly affected by seasonal variation that
33 might partly mask long-term variability (Schulz et al., 2013). Still, the surveys should be repeated on exactly
34 the same site (Galgani et al., 2013) that should not be subject to any other litter collection activity except the
35 monitoring survey; alternatively, the frequency and timing of the other beach cleaning (e.g., those carried
36 out every morning at dawn during the summer to please tourists) should be well known and documented
37 such that their influence on the litter flux rates can be determined. This information is generally missing in
38 the analysed scientific production. All these aspects make rather impossible the estimation of trends. As a
39 consequence, in the existing literature the assessment of the MBL temporal and spatial variability in a
40 surveyed areas is generally obtained through the comparison with data published in previous studies.
41 Normalized variables (e.g., density and/or weight per m²) help this task but a direct comparison often
42 neglects that different collections may have been realized taking advantage of different protocols and
43 guidelines.
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46 The selection of a specific coastal sites for the monitoring activities is another factor that can significantly
47 influence the comparability of the achieved results. Geomorphological and sedimentary characteristics, river
48 presence, meteo-oceanographic regimes, litter exposure (e.g., urban sites, rural coasts, marine protected
49 area), demographic and geographical conditions, main beach usage (i.e., recreational, fishing, surfing, boat
50 access) should be always considered and reported. Unfortunately, only few publications clearly define these
51 characteristics.
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1 Even more important is the choice of the MBL sampling unit. Both MSFD and OSPAR guidelines suggest a
2 minimum length of 100 m, which can be reduced to 50 m for heavily littered beaches, and a repetition of at
3 least two sections on the same beach. Even though most of the considered studies follow these
4 recommendations, a large number of collections opted for quadrats (of different sizes) and customized
5 criteria, instead of linear transects (Table 2). Inhomogeneity also exists in the use of transects which are
6 carried out parallel rather than perpendicular to the coast, at a different distance between each other, and
7 covering determined or variable beach width. Moreover, several studies do not report at all this information,
8 providing quantitative litter estimation that can be hardly comparable to other collections. This issue sums
9 to the fact that the observed data are sometimes expressed per beach length unit (m) rather than per beach
10 area unit (m²) in different MBL collections. Although per length unit can be more easily related to floating
11 litter fluxes washed ashore, most of the analysed studies do report MBL densities per beach area. However,
12 when the whole width of the beach is sampled, for equal litter counts, one must consider that per area
13 densities can increase as the width of the beach decreases, resulting in higher values for narrow beaches
14 data, and viceversa (Prevenios et al., 2018). Additionally, these quantitative estimates can refer to abundance
15 or weight (or even to volume in a few cases). This generates additional problems because estimations
16 obtained through weight-based surveys (in kg) cannot be directly compared to those based on the number
17 of items. A comparison between the two methodologies can be attempted when estimates of average
18 weights of the counted litter items are known. However, this would not be always possible since litter items
19 of the same materials occur on beaches in a wide range of sizes and weights.
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27 Furthermore, even though no upper size limits are applied to litter recorded on beaches, the analysed studies
28 shows that lower size limits can be very different from survey to survey. Actually, the lower limit should be
29 determined by the possibility of detection by the naked eye, thus being dependent on the surveyor's visual
30 perception (eyesight) and on the conspicuousness of the MBL items. This actually depends on litter
31 abundance, size, colour and form. The macro-MBL size lower limit is often identified around 0.5 cm. However,
32 it is doubtful that such small items can be monitored effectively during beach surveys in different locations
33 and by differently experienced personnel, e.g., trained scientists, volunteers (OSPAR, 2010a). In this sense, a
34 lower limit of 2.5 cm in the longest dimension seems more recommendable (Galgani et al., 2013), as applied
35 by the majority of the Mediterranean studies carried out in the recent years.
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40 The attribution of litter categories also plays an important role, as do different interpretations of monitoring
41 guidance. Generally, MBL composition is estimated by grouping the items into different predetermined
42 categories to favour comparability and compatibility of available observations. However, our analysis shows
43 that this classification is usually based on different codes in the existing literature (see Table 2). Different
44 classification schemes allow to report a different detail of information, from the raw material to the specific
45 type, or even brand, of single items, that can differently support additional litter analyses, such as source
46 attribution (e.g., Golik and Gertner, 1992; Renzi and Blaskovic, 2018). The available observations can still be
47 considered as a valuable proxy for the amount of litter present in a coastal environment. However, comparing
48 information collected in different areas/seasons/years, by different groups, is generally difficult and
49 represents a limit to the identification of priorities for action or effectiveness of mitigation measures.
50 Moreover, MBL data are usually not accompanied by proper uncertainties, so that they deserve a careful
51 metadata interpretation to evaluate their accuracy and reliability.
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57 Nevertheless, several analysed studies also attempted of determine top litter items over a specific region.
58 Unfortunately, the top items calculation modes were often different among surveys, as well as the category
59 lists and the top items ranking length. Consequently, even if data enable the ranking of items according to
60 their abundance, in many cases they cannot be directly compared with rankings from other collections due
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1 to the different monitoring techniques used. These issues add to the above-mentioned differences in MBL
2 sampling and reporting of the results, so that the aggregation of different studies proved to be often
3 unfeasible. Thus, obtaining comparable data and sampling strategies remains a priority to provide the basis
4 for reliable litter abundance rankings and previous studies integration. The final report of the EU ARCADIS
5 project, for example, lists the top fifteen MBL items for the Mediterranean Sea from 33 OSPAR screenings
6 indicating plastic cutlery/trays/straws as the dominant fraction (17%), followed by cigarette butts (14%),
7 plastic caps/lids (14%) and plastic drink bottles (12%) (Van Acoleyen et al., 2013). The report on Marine Litter
8 Assessment in the Mediterranean, instead, states that the main groups of items found on beaches in the
9 Mediterranean are sanitary items (mostly cotton bud sticks), cigarette butts and cigar tips, as well as
10 packaging items and bottles, all likely related to coastal-based tourism and recreation (UNEP/MAP MEDPOL,
11 2015). Several other surveys confirm that smoking related waste are a significant problem in the
12 Mediterranean, representing the most frequent items found on beaches, with abundances ranging from 35-
13 62% of the total items recorded (e.g., Martinez-Ribes et al., 2007; UNEP/MAP MEDPOL, 2011; Öko-Institut,
14 2012). Items related to uncontrolled discharges and inadequately managed waste also represent an
15 important problem in several Mediterranean countries (Makhoukh, 2012; Jambeck et al., 2015; UNEP/MAP
16 MEDPOL, 2015).

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22 The identification of the MBL source and pathway is another crucial step in determining the actions and
23 measures to reduce its impact in a given area. The above-mentioned protocols provide useful master lists
24 that relate item categories with potential sources of litter. Nonetheless, source identification is relatively
25 easy only for some items (e.g., fish box/nets; glass bottle in proximity of a beach bar). For the majority of
26 items, especially those fragmented or altered by long stay in the natural environment, it is much more
27 difficult to assign a source with a robust level of accuracy. The analysed Scopus dataset shows that several
28 methodological approaches have been used to determine where litter is coming from, but few information
29 is provided about value and limitations of the attribution of sources per type of item. Several studies, for
30 example, assume that all occurring items from a certain category originate from a particular source/pathway.
31 This is based on the assumption that certain items are typically or widely used by particular sectors (e.g.,
32 fishing, shipping, medical) and are conventionally released into the environment via specific pathways. Such
33 approaches can provide a preliminary indication of contribution of key sources. On the other hand, they
34 dismiss potential contributions from other sources (and/or pathways) and the importance of multiple
35 sources. To overcome these issues, several analysed studies do made use of attribution of sources based on
36 statistical techniques, such as the Matrix Scoring Technique that includes the likelihood criteria. Nonetheless,
37 a reliable likelihood analysis always deserves an accurate knowledge of the survey sites and its surroundings
38 to determine in advance a number of possible local and regional litter sources (e.g., tourism, fishing, shipping,
39 general littering, inadequate waste management, etc.). This information is rarely reported in the analysed
40 Scopus indexed literature.

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49 Another important issue is represented by litter removal during/after beach surveys, and the consequent
50 waste treatment. Actually, removal of litter should be carried out during monitoring activities. This is
51 important to ensure better accuracy of reporting, to allow the comparison of litter accumulation over time,
52 to reduce MBL impact on the ecosystems, and to leave a clean coastline to beach users (Galgani et al., 2013).
53 It is also very important limiting the quantity of sand and living organisms that could be removed during
54 manual/mechanical MBL collections (Zielinski et al., 2019). Among the analysed studies, several collections
55 rely on counting litter items without removing them from the coastline, or do not mention if/how MBL was
56 removed during/after beach surveys. When litter is removed, only a few documents provide details about
57 the expected impact of beach cleaning as a factor for loss of species abundance and changes to the beach
58 natural conditions (Defeo et al., 2009; Del Vecchio et al., 2017; Schneider et al., 2018). Information about the
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1 specific efforts to recruit, and train, field staff, are also missing in almost all of the analysed studies.
2 Nevertheless, this is essential to ensure data quality and prevent environment damages, especially when
3 citizen and volunteers are involved in the beach monitoring activities.

4 Finally, waste disposal and treatment also represent a tackling issue that deserves careful specific discussion.
5 Almost no information about waste treatment is available in the analysed publications, so that it is impossible
6 to evaluate the potential efforts in terms of reuse, recycle, energy recovery and landfill. Conversely, previous
7 projects demonstrated that, even if challenging, it is possible to reuse or recycle macro-litter, such as fish
8 nets, metals, lead line, polystyrene buoys (e.g., Northwest Straits Foundation, 2015; National Fish and
9 Wildlife Foundation, 2016; Iñiguez et al., 2016), turn them into art (Olive Ridley Project, 2017), or use them
10 to recover energy (Iñiguez et al., 2016).

11 5. Conclusions

12 In the last decades scientists, citizens and policy makers recognized MBL as a serious issue for coastal
13 ecosystems, human health and economical activities. Due to high anthropogenic pressure, intensive
14 economical exploitation and slow turnover of its waters, the Mediterranean Sea is particularly vulnerable to
15 this problem. A systematic review of current literature concerning MBL monitoring strategies along its coasts
16 shows that increasing efforts have been realized to monitor, study, and clean-up shorelines in the last two
17 decades.

18 Despite the ongoing efforts and initiatives to harmonize MBL monitoring over Mediterranean coasts, the
19 heterogeneity of the source data still represents a major challenge in terms of standardization of the data
20 management procedures and of data comparison. The presented extensive literature review points out that
21 these studies were generally characterized by significant differences in timing and frequency of the surveys,
22 in litter sampling and classification methodologies, as well as in the analysis and presentation of the collected
23 data. A large number of protocols for MBL monitoring exists, originally developed from a number of
24 campaigns over a thirty-year period. On the impulse of the MSFD, they are on the way to evolve into a
25 standardized monitoring tool. However, this task has not been achieved yet. Current MBL monitoring
26 activities follow different approaches, which somehow rely on the UNEP/IOP, OSPAR, NOAA and MSFD
27 guidelines, but they still miss harmonization in the strategy of survey, as well as in the analysis and
28 presentation of the collected observations. The choice of a particular type of survey often depends on the
29 objectives of the assessment, on the magnitude of the pollution, and on the typology on the coastline. Thus,
30 the comparison of MBL data between different assessment programmes is still difficult due to the use of
31 different methods, different spatial and temporal scales, different size scales of litter items, and different
32 lists or categorisation of litter items recorded on beaches. Consequently, even though some similarities can
33 be found, giving indications for intercomparison studies, the lack of standardization of the monitoring
34 protocols limit the integration of MBL data and the efforts to provide a pan-Mediterranean MBL temporal
35 and spatial analysis.

36 Nevertheless, the monitoring of MBL in Mediterranean Sea can be still considered a valid and important tool
37 for coastal environment conservation. Pressing research needs must be addressed as soon as possible. First
38 of all, it is essential to make easier a direct comparison of information collected by different groups/initiatives
39 and over different countries. Adopting consistent and harmonised criteria and methodological standards,
40 would ensure consistency of data and the possibility of meaningful comparison. To this goal, coordination at
41 a regional/national/Mediterranean level is urgently needed. Differently, an efficient monitoring system for
42 MBL cannot be permanently maintained. In this framework, it would be warmly welcome the improvement

1 and support to the use of shared platforms (e.g., EMODnet) to group and disseminate MBL observations, so
2 to homogenize the processing of datasets based on different protocols and reference systems, and facilitate
3 the identification of gaps and hindrances. Surveys and clean-up activities carried out along the southern
4 Mediterranean coasts, for example, are rarely reported in scientific publications, but they do exist.
5 Strengthening international collaborations across the Mediterranean would help this process. Similarly, it is
6 necessary to favour synergy between marine litter research in all environmental compartments (i.e., seafloor,
7 water column, sea surface, coast, biota). Making the data collected, raw and processed, public and easily
8 accessible, and having them available not only to the scientific community but also to policy makers and
9 stakeholders, would be important as well. To this goal, the shared methods of spatial and temporal
10 monitoring of Mediterranean beaches should be easy to follow by both scientists and volunteers. Collections
11 that can be conducted as part of the normal human presence in the marine environment, such as beach
12 clean-ups, appear interesting cost effective and environmentally friendly solutions (Schneider et al., 2018).
13 Involving more trained volunteers in MBL monitoring (e.g., through associations, schools, Citizen Science
14 projects) would, at the same time, arise the ecological awareness and support the scientific monitoring
15 efforts. This could also help create a communication channel between the world of research and policy
16 makers.
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22 Actually, a consistent increase in MBL monitoring efforts does not necessarily mean a significant reduction
23 of the overall stock of MBL. A growing and much larger amount of new waste, in particular plastics, is added
24 to the marine environment every year (Jambeck et al., 2015). A drastic input reduction is indeed necessary
25 to tackle the challenge of MBL effectively. Recognize the degree of waste decomposition, and improve its
26 treatment, as well as identifying the main sources is essential to design effective intervention strategies to
27 prevent litter from entering the marine environment. The allocation of likelihoods of MBL (e.g., through the
28 Matrix Scoring Technique) can provide a useful picture of sources and their relative importance in a certain
29 area. However, a number of indispensable factors must be enquired to characterize correctly a given region
30 (local topography and geography, human activities and their intensity, proximity to potential litter sources
31 or pathways). Again, this process needs shared guidelines, central coordination, local knowledge and
32 stakeholders' collaboration.
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38 In conclusion, despite the progresses recently achieved through several research activities, there is still an
39 urgent need to promote broad international collaboration in order to improve and harmonize scientific and
40 politics efforts to produce quality, open, and comparable MBL data over the Mediterranean basin (Sanchez-
41 Simon et al., 2022). Quality science is fundamental to engage and inform policy makers, stakeholders and
42 society to the goal of implementing effective measures, actions and regulations to tackle the challenging MBL
43 threats.
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48 **References**

- 49 Addamo, A.M., Laroche, P., Hanke, G., 2017. Top marine beach litter Items in Europe: a review and synthesis
50 based on beach litter data. In: JRC Technical Report EUR 29249 EN.
51
52 Addamo, A.M., Brosich, A., Chaves, M.D.M., Giorgetti, A., Hanke, G., Molina, E., Vinci, M., 2018. Marine litter
53 baselines: challenges and hindrances in compiling the first pan-European beach litter database. In: JRC
54 Technical Reports. JRC112895.
55
56
57 Afghan, A., Cerrano, C., Luzi, G., Calcinai, B., Puce, S., Pulido Mantas, T., Roveta, C., Di Camillo, C.G., 2020.
58 Main Anthropogenic Impacts on Benthic Macrofauna of Sandy Beaches: A Review J. Mar. Sci. Eng. 8, 405.
59
60
61
62
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- 1 Agamuthu, P., Mehran, S.B., Norkhairah, A., Norkhairiyah, A., 2019. Marine debris: a review of impacts and
2 global initiatives. *Waste Manag. Res.* 37 (10), 987–1002.
- 3 Alshawafi, A., Analla, M., Alwashali, E., Aksissou, M., 2017. Assessment of marine debris on the coastal
4 wetland of Martil in the North-East of Morocco. *Mar. Pollut. Bull.* 117, 302–310.
- 5
6 Angiolillo, M., and Fortibuoni, T. 2020. Impacts of marine litter on mediterranean reef systems: From shallow
7 to deep waters. *Front Mar Sci* 7, 581966.
- 8
9 Ansari, M., and Farzadkia, M. 2022. Beach debris quantity and composition around the world: A bibliometric
10 and systematic review. *Mar. Pollut. Bull.* 178, 113637.
- 11
12 Arthur, C., Baker, J., Bamford, H. Eds., 2009. Proceedings of the International Research Workshop on the
13 Occurrence, Effects and Fate of Microplastic Marine Debris, Tacoma, WA, USA, September 9-11, 2008. NOAA
14 Technical Memorandum NOS-OR&R-30.
- 15
16 Asensio-Montesinos, F., Anfuso, G., Randerson, P., Williams, A.T., 2019a. Seasonal comparison of beach litter
17 on Mediterranean coastal sites (Alicante, SE Spain). *Ocean Coast. Manag.* 181.
- 18
19 Asensio-Montesinos, F., Anfuso, G., Williams, A.T., 2019b. Beach litter distribution along the western
20 Mediterranean coast of Spain. *Mar. Pollut. Bull.* 141, 119–126.
- 21
22 Asensio-Montesinos, F., Anfuso, G., Aguilar-Torrelo, M.T., Oliva Ramirez, M., 2021a. Abundance and
23 Temporal Distribution of Beach Litter on the Coast of Ceuta (North Africa, Gibraltar Strait). *Water* 13, 2739.
- 24
25 Asensio-Montesinos, F., Anfuso, G., Williams, A.T., Sanz-Lazaro, C., 2021b. Litter behaviour on Mediterranean
26 cobble beaches, SE Spain. *Mar. Pollut. Bull.* 173, 113106.
- 27
28 Aulicino, G., Cotroneo, Y., Lacava, T., Sileo, G., Fusco, G., Carlon, R., Satriano, V., Pergola, N., Tramutoli, V.,
29 Budillon, G., 2016. Results of the first wave glider experiment in the southern Tyrrhenian Sea. *Adv. Oceanogr.*
30 *Limnol.* 7, 16–35.
- 31
32 Aulicino, G., Cotroneo, Y., Ruiz, S., Sanchez Roman, A., Pascual, A., Fusco, G., Tintoré, J., Budillon, G., 2018.
33 Monitoring the Algerian Basin through glider observations, satellite altimetry and numerical simulations
34 along a SARAL/AltiKa track. *J. Mar. Syst.* 179, 55–71.
- 35
36 Aydın C, Güven O, Salihoğlu B, et al., 2016. The influence of land use on coastal litter: An approach to identify
37 abundance and sources in the coastal area of Cilician Basin, Turkey. *Turkish J. Fish. Aquat. Sci.* 16, 29–39.
- 38
39 Battisti, C., Poeta, G., Pietrelli, L., Acosta, A.T., 2016. An unexpected consequence of plastic litter clean-up on
40 beaches: Too much sand might be removed. *Environ. Pr.* 18, 242–246.
- 41
42 Battisti, C., Kroha, S., Kozhuharova, E., De Michelis, S., Fanelli, G., Poeta, G., Pietrelli, L., Cerfolli, F., 2019.
43 Fishing lines and fishhooks as neglected marine litter: first data on chemical composition, densities, and
44 biological entrapment from a Mediterranean beach. *Environ. Sci. Pollut. Res.* 26, 1000–1007.
- 45
46 Benaissa, N., Haddad, F.Z., Taleb Bendiab, A.A., Bensahla-Talet, L., Hamou, A., Dimache, A., 2018. A
47 preliminary study on macro-litter pollution on beaches along Ain El Turk Bay. *Geo-Eco-Mar.* 27.
- 48
49 Bowman, D., Manor-Samsonov, N., Golik, A., 1998. Dynamics of litter pollution on Israeli Mediterranean
50 beaches: a budgetary, litter flux approach. *J. Coast. Res.* 14 (2), 418–432.
- 51
52 Bozzeda, F., Zangaro, F., Colangelo, M.A., Pinna, M., 2021. Relationships between size and abundance in
53 beach plastics: A power-law approach. *Mar. Pollut. Bull.* 173, 113005.
- 54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
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44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Brouwer, R., Hadzhiyska, D., Ioakeimidis, C., Ouderdorp, H., 2017. The social costs of marine litter along European coasts. *Ocean Coast. Manag.* 138, 38-49.

Camedda, A., Coppa, S., Palazzo, L., et al., 2021. Characterization and Assessment of Micro and Macroscopic Litter in Sardinian Beaches (Western Mediterranean Sea). *Water Air Soil Pollut.* 232, 41.

Cesarano, C., Aulicino, G., Cerrano, C., Ponti, M., Puce, S., 2021. Scientific knowledge on marine beach litter: A bibliometric analysis. *Mar. Pollut. Bull.* 173, 113102.

Cesarini, G., Cera, A., Battisti, C., Taurozzi, D., Scalici, M., 2021. Is the weight of plastic litter correlated with vegetal wrack? A case study from a Central Italian beach. *Mar. Pollut. Bull.*, 171, 112794.

Cheshire, A., Adler, E., Barbieri, J., Cohen, Y., Evans, S., Jarayabhand, S., Jeftic, L., Jung, R.T., Kinsey, S., Kusui, T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M. A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B., Westphalen, G., 2009. UNEP/IOC guidelines on survey and monitoring of marine litter. <https://wedocs.unep.org/20.500.11822/13604>.

Cole, M., Lindeque, P., Halsband, C., Galloway, T.S., 2011. Microplastics as contaminants in the marine environment: a review. *Mar. Pollut. Bull.* 62, 2588–2597.

Compa, M., Ventero, A., Iglesias, M., Deudero, S., 2018. Ingestion of microplastics and natural fibres in *Sardina pilchardus* (Walbaum, 1792) and *Engraulis encrasicolus* (Linnaeus, 1758) along the Spanish Mediterranean coast. *Mar. Pollut. Bull.* 128, 89–96.

Cotroneo, Y., Celentano, P., Aulicino, G., Perilli, A., Olita, A., Falco, P., Sorgente, R., Ribotti, A., Budillon, G., Fusco, G., Pessini, F., 2021. Connectivity analysis applied to mesoscale eddies in the Western Mediterranean basin. *Remote Sens.* 13, 4228.

Cózar, A., Sanz-Martín, M., Martí, E., I., J., G, G.-, Ubeda, B., Gálvez, J.Á., Irigoien, X., Duarte, C.M., 2015. Plastic accumulation in the Mediterranean Sea. *PLoS One* 10.

Cresta, E., Battisti, C., 2021. Anthropogenic litter along a coastal-wetland gradient: Reed-bed vegetation in the backdunes may act as a sink for expanded polystyrene. *Mar. Pollut. Bull.* 172, 112829.

de Francesco, M.C., Carranza, M.L., Stanisci, A., 2018. Beach litter in Mediterranean coastal dunes: an insight on the Adriatic coast (central Italy). *Rend. Lincei Sci. Fis. Nat.* 29, 825e830.

de Francesco, M.C., Carranza, M.L., Varricchione, M., Tozzi, F.P., Stanisci, A., 2019. Natural protected areas as special sentinels of littering on coastal dune vegetation. *Sustain. Times* 11, 1e16.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M., Scapini, F., 2009. Threats to sandy beach ecosystems: a review. *Estuar. Coast. Shelf Sci.* 81(1), 12.

Del Vecchio, S., Junker, T., Carboni, M., Acosta, A.T.R., 2017. Linking plant communities on land and at sea: the effects of *Posidonia oceanica* wrack on the structure of dune vegetation. *Science* 84, 30–36.

Dugan, J.E., Hubbard, D.M., Mccrary, M., Hubbard, D.M., Mccrary, M.D., Pierson, M.O., 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuar Coast Shelf Sci.* 58:25, 40.

EA/NALG, 2000. In: Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme. Environment Agency and The National Aquatic Litter Group, London, p. 15.

Ertas, A., 2021a. Assessment of origin and abundance of beach litter in Homa Lagoon coast, West Mediterranean Sea of Turkey Estuarine. *Estuar. Coast. Shelf Sci.* 249, 107114.

1 Ertas, 2021b. Assessment of beach litter pollution in Adana Akyatan Lagoon Coast of the East Mediterranean.
2 Mar. Pollut. Bull. 163, 111943.

3 European Commission, 2018a. Communication from the Commission: A European Strategy for Plastics in a
4 Circular Economy—Strategy, COM/2018/028.

5
6 European Commission, 2018b. Commission Staff Working Document Impact Assessment. Reducing Marine
7 Litter: action on single use plastics and fishing gear. Brussels, 28.5.2018, SWD(2018) 254, pp.76.

8
9 Fanini, L., Guittard, A., 2021. On single use plastic straws: Pre-ban findings on touristic beaches in Crete. Mar.
10 Pollut. Bull. 171, 112790.

11
12 Figueiredo Nascimento, S., Cuccillato, E., Schade, S., Guimarães Pereira, A. Joint Research Centre, 2016.
13 Citizen Engagement in Science and Policy-Making. Scientific and Technical Research Reports, Publications
14 Office of the European Union, EUR 28328 EN.

15
16 Forleo, M.B. and Romagnoli, L., 2021. Marine plastic litter: public perceptions and opinions in Italy. Mar.
17 Pollut. Bull. 165, 112160.

18
19 Fortibuoni, T., Ronchi, F., Macic, V., Mandic, M., Mazziotti, C., Peterlin, M., Prevenios, M., Prvan, M.,
20 Somarakis, S., Tutman, P., Varezic, D.B., Virsek, M.K., Vlachogianni, T., Zeri, C., 2019. A harmonized and
21 coordinated assessment of the abundance and composition of seafloor litter in the Adriatic-Ionian
22 macroregion (Mediterranean Sea). Mar. Pollut. Bull. 139, 412e426.

23
24 Fossi, M.C., Bainsi, M., Panti, C., Baulch, S., 2018. Impacts of Marine Litter on Cetaceans: A Focus on Plastic
25 Pollution, in: Fossi, M.C., Panti, C. (Eds), Marine Mammal Ecotoxicology, Academic Press, pp. 147-184, ISBN
26 9780128121443.

27
28 Fossi, M.C., Vlachogianni, T., Galgani, F., Innocenti, F.D., Zampetti, G., Leone, G., 2019. Assessing and
29 mitigating the harmful effects of plastic pollution: the collective multi-stakeholder driven Euro-
30 Mediterranean response. Ocean Coast Manag. 184, 105005.

31
32 Frias, J., Pagter, E., Nash, R., O'Connor, I., Carretero, O., Filgueiras, A., et al., 2018. Standardised protocol for
33 monitoring microplastics in sediments. JPI-OCEANS, BASEMAN, Deliverable 4.2.
34 <https://repository.oceanbestpractices.net/handle/11329/1206>. Accessed 20 January 2021.

35
36 Gabrielides, G.P., Golik, A., Loizides, L., Marino, M.G., Bingel, F., Torregrossa, M.V., 1991. Man-made garbage
37 pollution on the Mediterranean coastline. Mar. Pollut. Bull. 23, 437–441

38
39 Galgani, F., Hanke, G., Werner, S., Oosterbaan, L., Nilsson, P., Fleet, D., McKinsey, S., Thompson, R.,
40 VanFraneker, J., Vlachogianni, T., Scoullou, M., Mira, V.J., Palatinus, A., Matiddi, M., Maes, T., Korpinen, S.,
41 Budziak, A., Leslie, H., Gago, J., Liebezeit, G., 2013. MSFD technical group on Marine Litter, Guidance on
42 Monitoring of Marine Litter in European Seas. JRC Scientific and Policy rep483-490orts, SJRC83985, EUR
43 26113 ENI, SBN 978-92-79-32709-4. ISSN: 1831-9424.

44
45 Gall, S.C., Thompson, R.C., 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92, 170–179.

46
47 Giovacchini, A., Merlino, S., Locritani, M., Stroobant, M., 2018. Spatial distribution of marine litter along
48 Italian coastal areas in the Pelagos sanctuary (Ligurian Sea—NW Mediterranean Sea): A focus on natural and
49 urban beaches. Mar. Poll. Bull. 130, 140–152.

50
51 Gjyli, L., Vlachogianni, T., Kollitari, J., Matta, G., Metalla, O., Gjyli, S., 2020. Marine litter on the Albanian
52 coastline: baseline information for improved management. Ocean Coast Manag. 187, 105108.

53
54 Golik, A., Gertner, Y., 1992. Litter on the Israeli coastline. Mar. Environ. Res. 33 (1), 1–15.

55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
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45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Gönülal, O., Öz, I., Güreşen, S.O., Öztürk, B., 2016. Abundance and composition of marine litter around Gökçeada Island (Northern Aegean Sea), *Aquat. Ecosyst. Health Manag.* 19:4, 461-467.

Grelaud, M., Ziveri, P., 2020. The generation of marine litter in Mediterranean island beaches as an effect of tourism and its mitigation. *Sci. Rep.* 10, 20326.

Gundogdu, S., Cevik, C., 2019. Mediterranean dirty edge: High level of meso and macroplastics pollution on the Turkish coast. *Environ. Pollut.* 255, 113351.

Hanke, G., Galgani, F., Werner, S., Oosterbaan, L. et al., 2013. In: Hanke, G., Werner, S., Galgani, F., Veiga, J.M., Ferreira, M. (Eds.), *Guidance on Monitoring of Marine Litter in European Seas*. Edition: EUR – Scientific and Technical Research Series – ISSN 1831-9424 (Online). Publications Office of the European Union, Luxembourg. ISBN: 978-92-79-32709-4.

Hanke, G., Walvoort, D., van Loon, W., Addamo, A.M., Brosich, A., del Mar Chaves Montero, M., Molina Jack, M.E., Vinci, M., Giorgetti, A., 2019. *EU Marine Beach Litter Baselines*. Publications Office of the European Union, Luxembourg. EUR 30022 EN

Hidalgo-Ruz, V., Thiel, M., 2015. The contribution of citizen scientists to the monitoring of marine litter. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), *Marine anthropogenic litter*. Springer, Berlin, pp. 433–451.

Iniguez, M.E., Conesa, J.A., Fullana, A., 2016. Marine debris occurrence and treatment: a review. *Renew. Sust. Energ. Rev.* 64, 394–402.

Jambeck, J.R., Farfour, W.M., 2011. *Characterization of Individual Marine Debris Items by Mass*. 5th International Marine Debris Conference, April 2011, Honolulu, HI.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Law, K.L., 2015. Plastic waste inputs from land into the ocean. *Science* 347 (6223), 768–771.

Karkanorachaki, K., Kiparissis, S., Kalogerakis, G.C., Yiantzi, E., Psillakis, E., Kalogerakis, N., 2018. Plastic pellets, meso- and microplastics on the coastline of Northern Crete: distribution and organic pollution. *Mar. Pollut. Bull.* 133, 578–589.

Katsanevakis, S., 2015. Illegal immigration in the eastern Aegean Sea: a new source of marine litter. *Mediterr. Mar. Sci.* 16(3), 605-608.

Keswani, A., Oliver, D.M., Gutierrez, T., Quilliam, R.S., 2016. Microbial hitchhikers on marine plastic debris: human exposure risks at bathing waters and beach environments. *Mar. Environ. Res.* 118, 10–19.

Kiessling, T., Gutow, L., Thiel, M., 2015. Marine litter as habitat and dispersal vector. *Mar. Anthropol. Litter.* 141–181.

Kordella S., Geraga M., Papatheodorou G., Fakiris E., M. Mitropoulou I., 2013. Litter composition and source contribution for 80 beaches in Greece, Eastern Mediterranean: A nationwide voluntary clean-up campaign, *Aquat. Ecosyst. Health Manag.* 16 (1), 111-118.

Laglbauer, J.L.B., Franco-Santos, R.M., Andreu-Cazenave, M., Brunelli, L., Papadatou, M., Palatinus, A., Grego, M., Deprez, T., 2014. Macrodebris and microplastics from beaches in Slovenia. *Mar. Pollut. Bull.* 89, 356–366

Law, K.L., 2017. Plastics in the marine environment. *Annu. Rev. Mar. Sci.* 9, 205–229.

Li, W.C., Tse, H.F., Fok, L., 2016. Plastic waste in the marine environment: a review of sources, occurrence and effects. *Sci. Total Environ.* 566–567, 333–349.

1 Loizidou, X.I., Loizides, M.I., Orthodoxou, D.L., 2018. Persistent marine litter: small plastics and cigarette butts
2 remain on beaches after organized beach cleanups. *Environ. Monit. Assess.* 190 (7), 414.

3 Losh, S., 2015. A Proposed Method to Analyze Meso-And Microplastic Pollution on Beaches in Oregon. Honor.
4 Baccalaureate Sci. *Environ. Sci.* Oregon State University, University Honors College, Oregon, USA.

5
6 Lucrezi, S. and Digun-Aweto, O., 2020. "Who wants to join?" Visitors' willingness to participate in beach litter
7 clean-ups in Nigeria. *Mar Pollut. Bull.* 155, 111167.

8
9 Makhoukh, M., 2012. Pollution par les déchets solides en Algérie. Stratégie de gestion Intégrée des zones
10 côtières en Algérie? Bilan et diagnostic. MATE-PAP RAC 2012, 42 pages.

11
12 Mandić, M., Gvozdrenović, S., Peraš, I., Ivanović, A., Malovražić, N., 2021. Quantification and Classification of
13 Beach Litter in Montenegro (South-East Adriatic Sea). In: Joksimović, D., Đurović, M., Zonn, I.S., Kostianoy,
14 A.G., Semenov, A.V. (eds) *The Montenegrin Adriatic Coast. The Handbook of Environmental Chemistry*, 110,
15 Springer, Cham.

16
17
18 Martinez-Ribes, L., Basterretxea, G., Palmer, M., Tintoré, J., 2007. Origin and abundance of beach debris in
19 the Balearic islands. *Sci. Mar.* 71, 305–314.

20
21
22 Maziane, F., Nachite, D., Anfuso, G., 2018. Artificial polymer materials debris characteristics along the
23 Moroccan Mediterranean coast. *Mar. Pollut. Bull.* 128, 1-7.

24
25 MedSeaLitter EU Project, 2019. Available online: <https://medsealitter.interreg-med.eu>

26
27 Merlino, S., Paterni, M., Berton, A., Massetti, L., 2020. Unmanned aerial vehicles for debris survey in coastal
28 areas: long-term monitoring programme to study spatial and temporal accumulation of the dynamics of
29 beached marine litter. *Remote Sens.* 12, 1260.

30
31 Merlino, S., Paterni, M., Locritani, M., Andriolo, U., Gonçalves, G., Massetti, L., 2021. Citizen Science for
32 Marine Litter Detection and Classification on Unmanned Aerial Vehicle Images. *Water* 13(23), 3349.

33
34 Mghili, B., Analla, M., Aksissou, M., Aissa, C., 2020. Marine debris in Moroccan Mediterranean beaches: An
35 assessment of their abundance, composition and sources. *Mar. Pollut. Bull.* 160, 111692.

36
37
38 Mo, A., D'Antracoli, M., Bedinia, G., Ciccarelli, D., 2021. The role of plants in the face of marine litter invasion:
39 A case study in an Italian protected area. *Mar. Pollut. Bull.* 169, 112544.

40
41 Mocos, M., Zamora Martinez, I., Zubak, I., 2019. Is central Croatian Adriatic Sea under plastic attack?
42 Preliminary results of composition, abundance and sources of marine litter on three beaches. *Rend. Lincei*
43 *Sci. Fis. Nat.* 30, 797e806.

44
45 Mocos, M., Rokov, T., Zubak Čižmek, I., 2020. Monitoring and analysis of marine litter in Vodenjak cove on Iž
46 Island, central Croatian Adriatic Sea. *Rend. Lincei Sci. Fis. Nat.* 31, 905–912.

47
48 MSFD GES Technical Subgroup on Marine Litter, 2013. Guidance on monitoring of marine litter in European
49 seas. MSFD GES Technical Subgroup on Marine Litter 2013.

50
51
52 Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of
53 composition, spatial distribution and sources in north-western Adriatic beaches. *Waste Manag.* 49, 483–490.

54
55 Munari, C., Scoponi, M., Mistri, M., 2017. Plastic debris in the Mediterranean Sea: types, occurrence and
56 distribution along adriatic shorelines. *Waste Manag.* 67, 385e391.

57
58
59 Nachite, D., Maziane, F., Anfuso, G., Williams, A.T., 2019. Spatial and temporal variations of litter at the
60 Mediterranean beaches of Morocco mainly due to beach users. *Ocean Coast Manag.* 179, 1e14.

61
62
63
64
65

1 National Fish and Wildlife Foundation, 2016. Fishing for energy. Available at:
2 http://www.nfwf.org/fishingforenergy/Documents/ffe_factsheet_16-0329.pdf

3 Northwest Straits Foundation, 2015. Shallow water legacy derelict net removal from high priority areas of
4 puget sound. Available at: [http://www.nwstraitsfoundation.org/download/shallow-water-legacy-derelict-](http://www.nwstraitsfoundation.org/download/shallow-water-legacy-derelict-net-removal-fromhigh-priority-areas-of-puget-sound)
5 [net-removal-fromhigh-priority-areas-of-puget-sound](http://www.nwstraitsfoundation.org/download/shallow-water-legacy-derelict-net-removal-fromhigh-priority-areas-of-puget-sound).
6

7 Öko Institute, 2012. Study on Land sourced Litter in the Marine Environment. Review of sources and
8 literature. Öko Institut report, 128 pages.
9

10 Olive Ridley Project, 2017. News from the field. Available at:

11
12 Novi, L., Bracco, A., Falasca, F., 2021. Uncovering marine connectivity through sea surface temperature. Sci.
13 Rep. 11, 8839.
14

15
16 Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic
17 and Atmospheric Administration Marine Debris Program.
18

19 OSPAR, 2010a. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR area, Edition 1.0, ISBN
20 90 3631 973 9., 16 pp.
21

22 OSPAR, 2010b. OSPAR Beach Questionnaire 2010.012.
23

24 Özden, Ö., Yıldırım, S., Fuller, W.J., Godley, B.J., 2021. Anthropogenic marine litter on the north coast of
25 Cyprus: insights into marine pollution in the eastern Mediterranean. Mar. Pollut. Bull. 165, 112167.
26

27 Papachristopoulou, I., Filippides, A., Fakiris, E., Papatheodorou, G., 2020. Vessel based photographic
28 assessment of beach litter in remote coasts. A wide scale application in Saronikos Gulf, Greece. Mar. Pollut.
29 Bull. 150, 110684.
30

31 Pasternak, G., Zviely, D., Ribic, C.A., Ariel, A., Spanier, E., 2017. Sources, composition and spatial distribution
32 of marine debris along the Mediterranean coast of Israel. Mar. Pollut. Bull. 114 (2), 1036–1045.
33

34 Petry, M.V., Benemann, V.R., 2017. Ingestion of marine debris by the White-chinned Petrel (*Procellaria*
35 *aequinoctialis*): is it increasing over time off southern Brazil? Mar. Pollut. Bull. 117 (1–2), 131–135.
36

37 Pinardi, N., and Masetti, E. 2000. Variability of the large scale general circulation of the Mediterranean Sea
38 from observations and modelling: a review. *Palaeo* 158.
39

40 Poeta, G., Battisti, C., Acosta, A.T.R., 2014. Marine litter in Mediterranean sandy littorals: spatial distribution
41 patterns along Central Italy coastal dunes. Mar. Pollut. Bull. 89, 168–173.
42

43 Poeta, G., Conti, L., Malavasi, M., Battisti, C., Acosta, A.T.R., 2016a. Beach litter occurrence in sandy littorals:
44 the potential role of urban areas, rivers and beach users in central Italy. *Estuar. Coast. Shelf Sci.* 181, 231–
45 237.
46

47 Poeta, G., Battisti, C., Bazzichetto, M., Acosta, A.T.R., 2016b. The cotton buds beach: marine litter assessment
48 along the Tyrrhenian coast of central Italy following the marine strategy framework directive criteria. Mar.
49 Pollut. Bull. 113, 266–270.
50

51 Portman, M.E., Brennan, R.E., 2017. Marine litter from beach-based sources: case study of an Eastern
52 Mediterranean coastal town. *Waste Manag.* 69, 535–544.
53

54 Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter
55 dynamics on Mediterranean coasts: distinguishing sources and pathways. Mar. Pollut. Bull. 129 (2), 448–457.
56
57
58
59
60
61
62
63
64
65

- 1 Renzi, M., Blašković, A., 2018. Litter and microplastics features in table salts from marine origin: Italian versus
2 Croatian brands. *Mar. Pollut. Bull.* 135, 62-68.
- 3 Rodil, I.F., Harris, L.R., Lucrezi, S. and Cerrano, C., 2022. Sandy Beach Management and Conservation: The
4 Integration of Economic, Social and Ecological Values. In *Sandy Beaches as Endangered Ecosystems*, 251-294,
5 CRC Press.
- 6
7 Romiti, F., Pietrangeli, E., Battisti, C., Carpaneto, G.M., 2021. Quantifying the entrapment effect of
8 anthropogenic beach litter on sand-dwelling beetles according to the EU Marine Strategy Framework
9 Directive. *J. Insect Conserv.* 25, 441–452.
- 10
11 Schneider, F., Parsons, S., Clift, S., Stolte, A., McManus, M., 2018. Collected marine litter - a growing waste
12 challenge. *Mar. Pollut. Bull.* 128, 162–174
- 13
14 Schulz, M., Neumann, D., Fleet, D., Matthies, M., 2013. A multi-criteria evaluation system for marine litter
15 pollution based on statistical analyses of OSPAR beach litter monitoring time-series, *Mar. Environ. Res.* 92,
16 61-70.
- 17
18 Shiber, J.G., 1979. Plastic pellets on the coast of Lebanon. *Mar. Pollut. Bull.* 10, 28–30.
- 19
20 Shiber, J.G., 1982. Plastic pellets on Spain's Costa del Sol beaches. *Mar. Pollut. Bull.* 13, 409-412.
- 21
22 Shiber, J. G., 1987. Plastic pellets and tar on the beaches of the Mediterranean coast of Spain. *Mar. Pollut.*
23 *Bull.* 18, 84-86.
- 24
25 Shiber, J.G., Barrales-Rienda, J.M., 1991. Plastic pellets, tar and megalitter on Beirut beaches, 1977-1988.
26 *Environ. Pollut.* 71, 17-30.
- 27
28 Silc, U., Kūzmic, F., Cakovic, D., Stesevic, D., 2018. Beach litter along various sand dune habitats in the
29 southern Adriatic (E Mediterranean). *Mar. Pollut. Bull.* 128, 353e360.
- 30
31 Simon-Sánchez, L., Grelaud, M., Franci, M., Ziveri, P., 2022. Are research methods shaping our understanding
32 of microplastic pollution? A literature review on the seawater and sediment bodies of the Mediterranean
33 Sea, *Environ. Pollut.* 292, 118275.
- 34
35 Solo-Gabriele, H.M., Harwood, V.J., Kay, D., Fujioka, R.S., Sadowsky, M.J., Whitman, R.L., et al., 2016. Beach
36 sand and the potential for infectious disease transmission: observations and recommendations. *J. Mar. Biol.*
37 *Assoc. U.K.* 96, 1, 101–120.
- 38
39 Suaria, G., Aliani, S., 2014. Floating debris in the Mediterranean Sea. *Mar. Pollut. Bull.* 86, 494e504.
- 40
41 Suaria, G., Avio, C.G., Mineo, A., Lattin, G.L., Magaldi, M.G., Belmonte, G., Moore, C.J., Regoli, F., Aliani, S.,
42 2016. The mediterranean plastic soup: synthetic polymers in mediterranean surface waters. *Sci. Rep.* 6, 1e10.
- 43
44 Taïbi, N.-E., El Amine Bentaallah, M., Alomar, C., Compa, M., Deudero, S., 2021. Micro- and macro-plastics in
45 beach sediment of the Algerian western coast: First data on distribution, characterization, and source. *Mar.*
46 *Pollut. Bull.* 165, 112168.
- 47
48 Thompson, R.C., Moore, C., vom Saal, F.S., Swan, S.H., 2009. Plastics, the environment and human health:
49 current consensus and future trends. *Philos. Trans. R. Soc. B* 364, 2153–2166.
- 50
51 Tudor, D.T., Williams, A.T., Randerson, P., Ergin, A., Earll, R.E., 2002. The use of multivariate statistical
52 techniques to establish beach debris pollution sources. *J. Coast. Res.* 36, 716–725.
- 53
54 Tudor, D., Williams, A., 2004. Development of a 'Matrix Scoring Technique' to determine litter sources at a
55 Bristol Channel beach. *J. Coast. Conserv.* 9, 119-127.
- 56
57
58
59
60
61
62
63
64
65

- 1 UNEP/MAP MEDPOL, 2011. Assessment of the status of marine Litter in the Mediterranean Sea.
2 UNEP(DEPI)/MED WG.357/Inf.4.
- 3 UNEP/MAP, 2012. State of the Mediterranean Marine and Coastal Environment. UNEP/MAP, Athens,
4 Barcelona Convention.
5
- 6 UNEP/MAP, 2015. Marine Litter Assessment in the Mediterranean. ISBN: 978-92-807-3564-2.
7
- 8 UNEP/MAP MEDPOL, 2015. Updated Report on Marine Litter Assessment in the Mediterranean.
9 UNEP(DEPI)/MED WG.421/Inf.18.
10
- 11 UNEP/MAP, 2016. Integrated Monitoring and Assessment Guidance. UNEP(DEPI)/MED IG.22/Inf.7.
12
- 13 Van Acoleyen, M., Laureysens, I., Stijn, L., Raport, L., Van Sluis, C., Kater, B., et al., 2013. ARCADIS Final report
14 Marine Litter study to support the establishment of an initial quantitative headline reduction target
15 SFRA0025 European Commission DG Environment Project number BE0113.000668.
16
- 17 Veiga, J. M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., et al., 2016. Identifying sources of
18 marine litter. MSFD GES TG Marine Litter Thematic Report. JRC Technical Report.
19 <https://doi.org/10.2788/018068>.
20
21
- 22 Velandar, K.A., Mocogni, M., 1998. Maritime litter and sewage contamination at Cramond Beach Edinburgh
23 - a comparative study. *Mar. Pollut. Bull.* 36 (5), 385–389.
24
- 25 Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, Ch., Mazziotti, C., Tutman, P., Varezic, D.B., Palatinus, A.,
26 Trdan, S., Peterlin, M., Mandic, M., Markovic, O., Prvan, M., Kaberi, H., Prevenios, M., Kolutari, J., Kroqi, G.,
27 Fusco, M., Kalampokis, E., Scoullou, M., 2018. Marine litter on the beaches of the adriatic and ionian seas: an
28 assessment of their abundance, composition and sources. *Mar. Pollut. Bull.* 131 (A), 745–756.
29
30
- 31 Vlachogianni, T., Skocir, M., Constantin, P., Labbe, C., Orthodoxou, D., Pematzoglu, I., Scannella, D., Spika,
32 M., Zissimopoulos, V., Scoullou, M., 2020. Plastic pollution on the Mediterranean coastline: generating fit-
33 for-purpose data to support decisionmaking via a participatory-science initiative. *Sci. Total Environ.* 711,
34 135058.
35
36
- 37 Wenneker, B., Oosterbaan, L. 2010. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR
38 Maritime Area. OSPAR Commission. ISBN: 90-3631-973-9.
39
- 40 Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan,
41 L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm caused by marine litter. MSFD GES TG
42 Marine Litter – Thematic Report. JRC Technical report. EUR 28317 EN.
43
44
- 45 Wilcox, C., Mallos, N.J., Leonard, G.H., Rodriguez, A., Hardesty, B.D., 2016. Using expert elicitation to estimate
46 the impacts of plastic pollution on marine wildlife. *Mar. Policy* 65, 107–114.
47
48
- 49 Williams, A.T., Micallef, A., 2009. Beach Management. Principles and Practice. Earthscan, London, ISBN 978-
50 1-84407-435-8, 480 pp.
51
- 52 Williams, A.T., Rangel-Buitrago, N., 2019. Marine litter: solutions for a major environmental problem. *J. Coast.*
53 *Res.* 35 (3), 648–663
54
- 55 World Tourism Organization, 2018. UNWTO Tourism Highlights. 2018 edn, UNWTO, Madrid.
56
- 57 Zambianchi, E., Trani, M., Falco, P., 2017. Lagrangian transport of marine litter in the Mediterranean Sea.
58 *Front. Environ. Sci.* 103389.
59
60
61
62
63
64
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Zielinski, S., Botero, C.M., Yanes, A., 2019. To clean or not to clean? A critical review of beach cleaning methods and impacts. *Mar. Pollut. Bull.* 139, 390–401.

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Marine beach litter monitoring **strategies** along Mediterranean coasts. A methodological review

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Abstract

Marine beach litter (MBL) represents a serious issue for marine life, coastal ecosystems, human health and several economical activities. The Mediterranean Sea is a semi enclosed basin particularly vulnerable to this problem. Its coasts are threatened by critical anthropogenic pressures that sum up with intensive fishing and shipping, and the slow turnover of its waters. In the last decades, several scientific and participative initiatives have been conducted to study, monitor and clean-up shorelines. These studies were generally characterized by differences in timing and frequency of the surveys, as well as in litter sampling, classification and analysis. This paper presents a systematic review of current literature concerning MBL monitoring **strategies** along the Mediterranean coasts. Scopus indexed studies are analysed to identify **discrepancies and similarities among the applied protocols**, understand where current gaps lie, and point out what would be needed to develop a basin-scale efficient monitoring for the Mediterranean Sea.

1. Introduction

Beaches were only recently recognized as ecosystems (McLachlan and Erasmus 1983) but the public perception is very far from this awareness (Rodil et al., 2022). Marine litter, particularly plastic pollution, are paradoxically helping in the valorisation of coastal habitats, being visible along the coast and triggering a strong perception that is important to take action to limit this kind of pollution (Lucrezi and Digun-Aweto, 2020). Marine litter is defined as "any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment" (MSFD GES Technical Subgroup on Marine Litter, 2013). It includes items or fragments that have been directly discarded on the beaches (e.g., coastal and beach tourism, recreational activities), those that have been somehow transported from land to the sea (e.g., households, agriculture, illegal dumping, input by rivers, wind and land run-off) and those coming from ocean-based sources (e.g., storm water overflows, off-shore industries, commercial shipping, fisheries, port activities and boating). Marine litter can also be transported over long distances by ocean currents before being deposited, so that it is found in all marine compartments such as beaches, on the shallow and deep seafloor, in the sea surface layer and in the water column, in sediments and sea ice (Law, 2017; Addamo et al. 2017). Thus, the marine environment can be considered as a sink in which anthropogenic litter accumulates (Van Acoleyen et al., 2013) coming from land-based and offshore sources (Veiga et al., 2016).

This implies that marine beach litter (MBL) found in a given area can be of local origin, can arrive from inland or can be transported from distant regions via ocean currents and the prevailing wind. Source and origin

1 identification is usually very difficult, especially when the litter items are fragments resulting from the
2 disintegration of larger items that spent long time along the pathways system. This is the case of microplastics
3 (i.e., small pieces of plastic litter < 0.5 cm in diameter, Arthur et al. 2009) that represent a serious global
4 problem causing harm to marine wildlife, coastal communities and maritime activities (Veiga et al., 2016).
5 Due to their persistent nature and their potential to cause undesirable effects, MBL has detrimental impact
6 on marine biota at different levels of biological organisation and habitats, environment, human health, as
7 well as economy (Gall and Thompson, 2015; Schneider et al., 2018; Agamuthu et al., 2019). Marine litter can
8 also act as a vector for spread of invasive species altering or modifying assemblages of species (Kießling et
9 al., 2015; Werner et al., 2016) or as vehicles for chemicals and contaminants, which may be absorbed on to
10 their surface (e.g., phthalates, polycyclic aromatic hydrocarbons (PAH), brominated flame retardants (BFR),
11 polychlorinated biphenyl (PCB), dichlorodiphenyltrichloroethane (DDT) – see Cole et al., 2011) and become
12 bioavailable accumulating along the biological food chain (Li et al., 2016; Fossi et al., 2018). Finally, MBL is
13 eyesore and aesthetically unpleasant causing landscape degradation and negative public perception leading
14 to a decline in tourism, and subsequent income loss, when washed ashore on beaches (Keswani et al., 2016;
15 Pasternak et al., 2017; Forleo and Romagnoli, 2021).

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21 Although no evidence of permanent garbage patches has been reported so far (Cózar et al. 2015), the
22 Mediterranean Sea has been recognized as one of the most vulnerable areas in the world by MBL (e.g.,
23 UNEP/MAP, 2015; Suaria et al., 2016; Fossi et al., 2019; Grelaud and Ziveri, 2020). It is a semi-enclosed basin
24 characterized by complex anti-estuarine circulation (Pinardi and Masetti, 2000; Cotroneo et al., 2021), slow
25 water overturning and the presence of intense gyres and mesoscale eddies (Aulicino et al., 2016; 2018) that
26 favour the potential accumulation of floating plastic debris (Suaria and Aliani, 2014; Zambianchi et al., 2017;
27 Compa et al., 2020). In addition, coastal population of nearly 150 million inhabitants and an intensive growing
28 tourism pressure, estimated in about one third of the world tourist presences (World Tourism Organization,
29 2018), make its coasts densely populated. Also, the Mediterranean Sea hosts about 15 to 30% of the global
30 shipping activity (UNEP/MAP, 2012) and represents an area of intense commercial fishing. This potential high
31 contamination goes hand to hand with a stream of adverse effects to marine ecosystems, public health and
32 socio-economic costs at local, regional and basin scales (Thompson et al., 2009; Wilcox et al., 2016; Solo-
33 Gabriele et al., 2016; Brouwer et al., 2017; Angiolillo and Fortibuoni, 2020).

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39 In this scenario, reducing litter in the Mediterranean coastal and marine environment is recognised as a
40 priority challenge to preserve the ecosystem and human health, and avoid adverse economic and aesthetic
41 impacts (Addamo et al., 2018). Specific measures aimed at preventing further inputs and reducing the
42 abundance of litter items need the determination of marine litter composition and distribution patterns, as
43 well as sources and pathways (Addamo et al., 2017; European Commission, 2018a; 2018b). A guidance
44 document produced by the MSFD Technical Group on Marine Litter (MSFD TG-ML) suggested five comparts
45 for monitoring marine litter in European Seas, i.e., beach litter, sea floor litter, floating litter, litter in biota
46 and micro-litter (MSFD GES Technical Subgroup on Marine Litter, 2013). Of these, MBL was expected to be
47 the most mature indicator and the one for which the most data could be easily available (Van Acoleyen et
48 al., 2013). The Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast
49 (IMAP), adopted by all Mediterranean countries in 2016, also includes indicator 22, which deals with litter
50 deposited on the coastline (UNEP/MAP, 2016).

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56 Even though it is more representative of land-based sources than that which is deposited far offshore, and
57 the ratio between sea-based and land-based sources may vary considerably between the regional seas, MBL
58 accumulation may be easier monitored and estimated than along water column or onto seabed (Schneider
59 et al., 2018). Generally, MBL monitoring constitutes a cost-effective methodology and its results can be
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1 considered somewhat representative of new litter entering the coastal environment. In particular, this is true
2 for urban beaches and those geographically under the influence of specific activities and discharges (Van
3 Acoleyen et al., 2013). Moreover, information on the temporal and spatial distribution of marine litter found
4 stranded on beaches can be effectively provided by non-government organizations (NGOs) and participatory
5 science campaigns (UNEP/MAP, 2015; Hidalgo-Ruz and Thiel, 2015) that also encourage communities to take
6 up actions toward responsible behaviours and fill in the knowledge gaps (Figueiredo Nascimento et al., 2016;
7 Hanke et al., 2019; Vlachogianni et al., 2020).

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10 Nevertheless, the increasing efforts to survey offshore areas aimed to improve the knowledge of marine litter
11 dispersal, concentration and type (e.g., MedSeaLitter EU Project, 2019), have not been always accompanied
12 in the Mediterranean by an equally increasing interest in the homogenization of the protocols and
13 methodologies devoted to the collection of reliable, coherent and comparable data of the composition and
14 distribution of MBL (Merlino et al., 2020). The number of MBL studies published to-date in peer-review
15 journals remains limited and often dedicated to specific coastal areas (Vlachogianni et al., 2020). Additionally,
16 these studies are generally characterized by differences in timing and frequency of the surveys, as well as by
17 discrepancies in litter sampling and classification, data analysis and waste disposal (e.g., Galgani et al., 2013;
18 Wenneker and Oosterbaan, 2010; Papachristopoulou et al., 2020; Grelaud and Ziveri, 2020; Vlachogianni et
19 al., 2020; Fortibuoni et al., 2021; Simon-Sanchez et al., 2022). It is extremely difficult to understand to what
20 extent the data produced are comparable or limited by the different methods.

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22 In this context, the present study reviews current literature relating to the monitoring and collection of MBL
23 over the Mediterranean coasts through bibliometric and content analyses, in order to compile information
24 about the applied monitoring strategies. Data collection takes advantage of the Scopus scientific database.
25 Based on this dataset, the discrepancies and similarities in the methods are analysed to identify where
26 current gaps lie and to point out what would be needed to progress in developing a basin-scale efficient
27 monitoring for the Mediterranean Sea. Moreover, we reaffirm the necessity of improving international
28 collaboration between Mediterranean countries, including the harmonization of directives and protocols
29 between European and North African countries, to provide a complete picture of the MBL pollution status in
30 this basin.

31 32 33 34 35 36 37 38 39 **2. Methods**

40 **2.1 Literature search**

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42 A systematic literature review was conducted to compile the MBL studies along the Mediterranean Sea coasts
43 and the associated [monitoring strategies](#). In the first step, the Scopus, Elsevier scientific database
44 (www.scopus.com) was consulted, integrating logical operators, through specific string search. The search
45 was limited to English peer-reviewed articles published before 31st December, 2021.

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48 [Taking advantage of the information about MBL queries provided by the same authors in Cesarano et al.](#)
49 [\(2021\), the search string was set to << beach* AND \(marine OR coast*\) AND \(litter OR debris OR waste OR](#)
50 [*plastic\) >>, in conjunction with << Mediterranean >> and the main regional terms referring to its main sub-](#)
51 [basins, in the “Article title”, “Abstract” or “Keywords”. This query resulted in 255 documents published](#)
52 [between 1978 and 2021 \(see details in Supplemental material, Table S1\). This dataset was exported as .csv](#)
53 [file including all the information provided by Scopus, i.e., “Citation Information”, “Bibliographic Information”,](#)
54 [“Abstract”, “Keywords” and “References”. To refine this dataset, the documents were further screened by](#)
55 [reading the titles and abstracts followed by the exclusion of those that were irrelevant to the objective of](#)
56 [this study \(Afghan et al., 2020\). In the third and last step, the documents were thoroughly screened \(i.e.,](#)
57 [through full-text reading\) to identify those eligible for the present analysis. The meeting criteria for inclusion](#)
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in the following content analysis (see Section 2.2) was that the study must be addressing the data collection and/or analysis of macro-MBL (i.e., items ≥ 0.5 cm) over the Mediterranean shoreline, and providing details about the protocols and the methodologies applied. According to these criteria, the documents relating exclusively to micro-MBL were excluded at this stage. A stepwise sketch of the searching strategy is given as Figure 1.

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| 1 | Literature search <i>TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (mediterranean OR tyrrhenian OR balearic OR aegean OR adriatic OR ionian OR levantine OR alboran OR israel* OR ligur* OR tunisi* OR egypt* OR algerian))</i> Peer-reviewed articles before 31 st December 2021 | Documents 255 |
| 2 | Title and abstract screening | Documents 255 Out of scope - 105 |
| 3 | Full text review | Documents 150 Excluded - 92 |
| 4 | Content analysis | Documents 58 |

Fig. 1. Flow diagram illustrating the selection process and systematic review of the published literature.

2.2 Content analysis

After the full-text review, a content analysis was carried out extracting from each included study, and bringing together, information about the surveyed area, the sampling timing and the applied methodologies. In particular, the data concern: the locations, dates and frequency of the monitoring campaign; the number and characteristics (i.e., coastal type and beach typology) of surveyed sites; the description of the applied protocols and classification strategy (e.g., sampling unit and methodology, macro-litter definition size, number of examined categories); the total surveyed area and the total number/weight of the collected items; the performed statistical analysis.

This analysis provides a fairly comprehensive overview of the strategies adopted for monitoring macro-MBL along the Mediterranean coast as reported in Scopus indexed scientific articles, the occurrence of the sampling activities and the identification of the most (and least) investigated areas.

3. Results

3.1. Bibliometric research and data collection

The bibliometric analysis started with title and abstract screening of the selected articles (i.e., step 2 in Figure 1). Among them, 105 documents were discarded because out of the scope of this review since they were related to different environmental compartments (i.e., water surface, seafloor, sediment, biota), study areas (e.g., Atlantic Ocean), or disciplines (see details in Table S2). The full text review (i.e., step 3 in Figure 1) further reduced the eligible documents to 58 articles that were included in the following bibliometric and content analyses. Tables are presented in the following sections bringing together data from these

publications, specifying the locations, dates, frequency, and main sampling details of each survey (see Tables 1 to 3).

3.2. Temporal analysis

The bibliometric analysis draws data from 58 documents published between 1991 and 2021 (Table 1). The leading journal is *Marine Pollution Bulletin* that hosted about 42% of the Scopus indexed publications on the Mediterranean macro-MBL data [monitoring activities](#). The temporal distribution of these documents indicates a consistent increase of the interest in this topic over the last decade (Figure 2). After a few pioneering studies focused on pellets, dated to late 70s and 80s (Shiber, 1979; 1982; 1987), the first articles on this topic appeared in the early 90s (e.g., Shiber and Barrales-Rienda, 1991; Gabrielides et al., 1991; Golik and Gertner, 1992). Nonetheless, the research interest in macro-MBL over the Mediterranean coasts was extremely modest during the 90s (Bowman et al., 1998) and 2000s (Tudor et al., 2002; Martinez-Ribes et al., 2007) and mostly devoted to specific regions (e.g., Israeli and Spanish beaches). The number of available scientific studies began to grow substantially since 2013 and continued to increase considerably through 2021. This is possibly a response to the overall rise of awareness towards the problem following the long-term accumulation of litter in the ocean and along the shoreline (Petry and Benemann, 2017; Schneider et al., 2018), and to the release of the MSFD guidance on monitoring of marine litter in European seas (Galgani et al., 2013). For example, the high number of studies published in 2021 (Figure 2) sum up the sampling efforts of the previous years when several projects were carried out in the framework of the Marine Strategy activities 2015-2020.

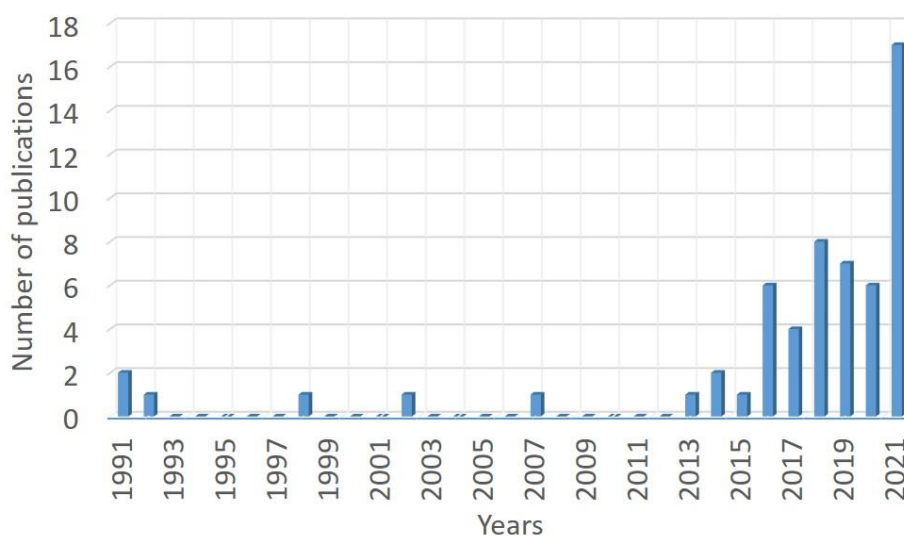


Fig. 2. Number of publications indexed in Scopus per year (1991–2021) dealing with macro-MBL monitoring.

A deeper analysis of the information reported in the selected publications shows that MBL scientific collection projects are typically conducted over a limited and short period of time covering two years or less (Table 1). The majority were collection activities and/or experiments that were started and completed within the same year. Actually, a third of the publications (19 of 58) reports about single-day surveys. Only 9 publications deal with macro-MBL monitoring activities characterized by a seasonal revisit time, as advised by international methodological indications (e.g., UNEP/MAP, 2016). A similar fraction, indeed, opted for monthly repetitions, while three monitoring projects were performed on a 15-days basis but over a shorter time period (i.e., four months). Other research activities are organized following different temporal strategies according to specific criteria, for example to have an overview of marine debris characteristics and

distribution before/after the touristic season (e.g., Grelaud and Ziveri, 2020), the periods in which beach cleaning operations are (are not) carried out (e.g., Nachite et al., 2019), or the realization of citizen awareness programmes.

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Table 1. Extracted temporal and geographical data from enquired Scopus indexed scientific surveys. Countries are reported through the ISO 3166-1 alpha2 code. Sites located in protected areas are indicated in cyano. Colours identify publications reporting information about beach typology (blue), coastal types (green) or both (red). Sites located in protected areas are indicated in blue (additional details in Table S3).

| ID | Reference | Time period | Frequence and timing | Number of sites | Location | Country | Journal |
|----|--|-------------|--|-----------------|--------------------------------------|--------------------|--|
| 1 | Shiber and Barrales-Rienda, 1991 | 1978 - 1978 | Twice per week (Jul) | 5 | Beirut | LB | Environmental Pollution |
| 2 | Shiber and Barrales-Rienda, 1991 | 1988 - 1988 | Three times (Mar, Apr) | 3 | Beirut | LB | Environmental Pollution |
| 3 | Golik and Gertner, 1992 | 1988 - 1989 | Monthly (May - May) | 6 | Israeli coast | IL | Marine Environmental Research |
| 4 | Gabrielides et al., 1991 | 1988 - 1989 | Monthly (May - May) | 13 | Spain, Italy, Turkey, Cyprus, Israel | ES, IT, TR, CY, IL | Marine Pollution Bulletin |
| 5 | Bowman et al., 1998 | 1990 - 1991 | Monthly (Jul - Oct) | 6 | Israeli coast | IL | Journal of Coastal Research |
| 6 | Tudor et al., 2002 | 1998 - 2000 | Single/multiple surveys per beach site | 7 | Turkey, Malta, Spain, Tunisia | TR, ES, MT, TN | Journal of Coastal Research |
| 7 | Martinez-Ribes et al., 2007 | 2005 - 2005 | Monthly (Apr, Jun - Sep) | 32 | Balearic Islands | ES | Scientia Marina |
| 8 | Kordella et al., 2013 | 2006 - 2007 | Once | 80 | Greece | GR | Aquatic Ecosystem Health and Management |
| 9 | Poeta et al., 2014; Poeta et al., 2016a | 2012 - 2012 | Once (Apr, May) | 5 | Lazio coast | IT | Marine Pollution Bulletin; Estuarine, Coastal and Shelf Science |
| 10 | Laglbauer et al., 2014 | 2012 - 2012 | Once (Jul) | 6 | Slovenia | SI | Marine Pollution Bulletin |
| 11 | Pasternak et al., 2017 | 2012 - 2015 | 14 to 19 surveys per beach site | 8 | Israeli coast | IL | Marine Pollution Bulletin |
| 12 | Gonulal et al., 2016 | 2013 - 2015 | Once | 14 | Gokceada Island | TR | Aquatic Ecosystem Health and Management |
| 13 | Camedda et al., 2021 | 2013 - 2016 | Twice a year (autumn, spring) | 7 | Sardinia | IT | Water Air and Soil Pollution |
| 14 | Karkanorachaki et al., 2018 | 2014 - 2014 | Summer (Apr - Jun), winter (Nov - Mar) | 4 | Northern Crete | GR | Marine Pollution Bulletin |
| 15 | Aydin et al., 2016 | 2014 - 2014 | Once (Apr) | 13 | Cilician Basin | TR | Turkish Journal of Fisheries and Aquatic Sciences |
| 16 | de Francesco et al., 2018 | 2014 - 2015 | Spring | 3 | Abruzzo e Molise | IT | Rendiconti Lincei. Scienze Fisiche e Naturali |
| 17 | Prevenios et al., 2018 | 2014 - 2015 | Every ~15 days (Jul - Oct) | 4 | Corfu Island | GR | Marine Pollution Bulletin |
| 18 | Poeta et al., 2016b | 2014 - 2015 | Spring, summer, autumn, winter | 3 | Montalto Marina | IT | Marine Pollution Bulletin |
| 19 | Giovacchini et al., 2018 | 2014 - 2015 | Spring, summer, autumn, winter | 11 | Pelagos sanctuary (Ligurian Sea) | IT | Marine Pollution Bulletin |

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| 20 | Vlachogianni et al., 2018 | 2014 - 2016 | Autumn, winter, spring, summer | 31 | Adriatic Sea | AL, BA, HR, GR, IT, MO, SL | Marine Pollution Bulletin |
| 21 | Alshawafi et al., 2017 | 2015 - 2015 | Spring, summer, autumn, winter | 1 | Martil | MA | Marine Pollution Bulletin |
| 22 | Maziane et al., 2018 | 2015 - 2015 | Once (Nov - Dec) | 14 | Mediterranean coast of Morocco | MA | Marine Pollution Bulletin |
| 23 | Munari et al., 2016 | 2015 - 2015 | Once (May - Jun) | 5 | North-western Adriatic coast | IT | Waste Management |
| 24 | Munari et al., 2017 | 2015 - 2015 | Once (May) | 5 | North-western Adriatic coast | IT | Waste Management |
| 25 | Nachite et al., 2019 | 2015 - 2017 | Twice a year (autumn, spring) | 14 | Alboran Sea | MA | Ocean and Coastal Management |
| 26 | Fortibuoni et al., 2021 | 2015 - 2017 | Twice a year (spring, autumn) | 64 | Italy | IT | Environmental Pollution |
| 27 | Portman and Brennan, 2017 | 2016 - 2016 | Every ~15 days (Apr - Jul) | 3 | Jisr-Az-Zarqa | IL | Waste Management |
| 28 | Loizidou et al., 2018 | 2016 - 2017 | Once (May - Aug) | 9 | Island of Cyprus | CY | Environmental Monitoring and Assessment |
| 29 | Papachristopoulou et al., 2020 | 2017 - 2018 | Summer, autumn, winter, spring | 62 | Western Saronikos Gulf | GR | Marine Pollution Bulletin |
| 30 | Ozden et al., 2021 | 2017 - 2019 | Monthly (Jan - Jan) | 8 | Northern Cyprus | CY | Marine Pollution Bulletin |
| 31 | Grelaud and Ziveri, 2020 | 2017 - 2019 | Monthly (Feb - Nov 2017, Aug - Sep 2019) | 35 | Mallorca, Sicily, Rab, Malta, Crete, Cyprus, Mykonos, Rhodes, | ES, IT, HR, MT, GR, CY | Scientific Reports |
| 32 | Silc et al., 2018 | 2017 -2017 | Once (May) | 1 | Velika plaža | ME | Marine Pollution Bulletin |
| 33 | Taibi et al., 2021 | 2017 -2017 | 10 - 21 replicates per beach site (Feb - Jul) | 9 | Western Algerian coast | DZ | Marine Pollution Bulletin |
| 34 | Gundogdu and Cevik, 2019 | 2018 - 2018 | Once (May) | 13 | Iskenderun Bay | TR | Environmental Pollution |
| 35 | de Francesco et al., 2019 | 2018 - 2018 | Once (Apr – May) | 7 | Abruzzo e Molise | IT | Sustainability |
| 36 | Gjyli et al., 2020 | 2018 - 2018 | Once (Apr) | 5 | Albanian coastline | AL | Ocean and Coastal Management |
| 37 | Asensio-Montesinos et al., 2019a | 2018 - 2018 | Once (Mar) | 56 | Alicante coast | ES | Marine Pollution Bulletin |
| 38 | Asensio-Montesinos et al., 2019b | 2018 - 2018 | Twice (Mar, Aug) | 56 | Alicante coast | ES | Ocean and Coastal Management |
| 39 | Mokos et al., 2019 | 2018 - 2018 | Once (Mar - May) | 3 | Croatian Adriatic Sea | HR | Rendiconti Lincei. Scienze Fisiche e Naturali |
| 40 | Vlachogianni et al., 2020 | 2018 - 2018 | Twice (autumn, winter) | 23 | Croatia, Cyprus, France, Greece, Italy | HR, CY, FR, GR, IT | Science of the Total Environment |
| 41 | Mo et al., 2021 | 2018 - 2018 | Twice (spring, autumn) | 3 | Ligurian Sea, Tuscany | IT | Marine Pollution Bulletin |
| 42 | Battisti et al., 2019 | 2018 - 2018 | Once (Mar) | 1 | Torre Flavia wetland | IT | Environmental Science and Pollution Research |

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| 43 | Mandic et al., 2021 | 2018 - 2019 | Three times (autumn, winter, spring) | 2 | Montenegrin coast | MO | The Montenegrin Adriatic Coast: Marine Chemistry Pollution |
| 44 | Mokos et al., 2020 | 2018 - 2019 | Summer, autumn, winter, spring | 1 | Vodenjak cove | HR | Rendiconti Lincei. Scienze Fisiche e Naturali |
| 45 | Bozzeda et al., 2021 | 2019 - 2019 | Once (Apr) | 1 | Aquatina | IT | Marine Pollution Bulletin |
| 46 | Asensio-Montesinos et al., 2021a | 2019 - 2019 | Monthly (Feb - Apr) | 12 | Ceuta | ES | Water MDPI |
| 47 | Romiti et al., 2021 | 2019 - 2019 | Monthly (Apr - Jun) | 2 | Ionian coast of the Calabria | IT | Journal of Insect Conservation |
| 48 | Fanini and Guittard, 2021 | 2019 - 2019 | Weekly (Apr - Sep), twice (Nov - Dec) | 2 | Island of Crete | GR | Marine Pollution Bulletin |
| 49 | Mghili et al., 2020 | 2019 - 2019 | Winter, spring, summer, autumn | 5 | Mediterranean coast of Morocco | MA | Marine Pollution Bulletin |
| 50 | Cesarini et al., 2021 | 2019 - 2019 | Once (Nov) | 1 | Torre Flavia wetland | IT | Marine Pollution Bulletin |
| 51 | Benaissa et al., 2021 | 2019 - 2019 | Once (Mar - Apr) | 10 | Aïn el Turk Bay | DZ | Geo-Eco-Marina |
| 52 | Ertas, 2021b | 2019 - 2020 | Summer, autumn, winter, spring | 1 | Adana Akyatan Lagoon Coast | TR | Marine Pollution Bulletin |
| 53 | Ertas, 2021a | 2019 - 2020 | Winter, spring, summer, autumn | 1 | Homa Lagoon coast | TR | Estuarine, Coastal and Shelf Science |
| 54 | Asensio-Montesinos et al., 2021b | 2020 - 2021 | Every ~15 days (Dec - Mar) | 5 | Alicante province | ES | Marine Pollution Bulletin |
| 55 | Cresta and Battisti, 2021 | 2021 - 2021 | Twice (Apr, May) | 1 | Torre Flavia wetland | IT | Marine Pollution Bulletin |
| 56 | Merlino et al., 2021 | 2021 - 2021 | Once (May) | 1 | Migliarino, Massacciucoli and San Rossore park | IT | Water |
| 57 | Katsanevakis, 2015 | NA | NA | 2 | Lesvos Island | GR | Mediterranean Marine Science |
| 58 | Battisti et al., 2016 | NA | NA | 1 | Torre Flavia wetland | IT | Environmental Practice |

3.3. Beach distribution and typology

At present there is no agreed statistical method for recommending a minimum number of sites that may be representative for a certain length of coast. This depends greatly on the purpose of the monitoring, on the geomorphology of the coast and how many sites that meet the sampling criteria are available (Galgani et al., 2013).

Figure 3 positions the reviewed macro-MBL collections. Generally, scientific efforts tend to focus on the European Mediterranean Sea. Information about the African coasts are largely missing, with the exception of Morocco (e.g., Maziane et al., 2018; Nachite et al., 2019; Mghili et al., 2020) and Algeria (Benaissa et al., 2021). Additional investigation is needed to determine whether those areas have been surveyed but not reported in scientific publications. Italy and Greece undertake major efforts, but also Israel, Cyprus and the Balkan countries are largely represented (Table 1). Consequently, Tyrrhenian, Adriatic and Aegean coasts are the most surveyed among the Mediterranean sub-basins (Figure 3). Conversely, several monitoring activities promoted by France, Spain and Turkey, which actually cover a larger fraction of their long coastline, are missing in scientific literature and do not appear in this bibliometric research.

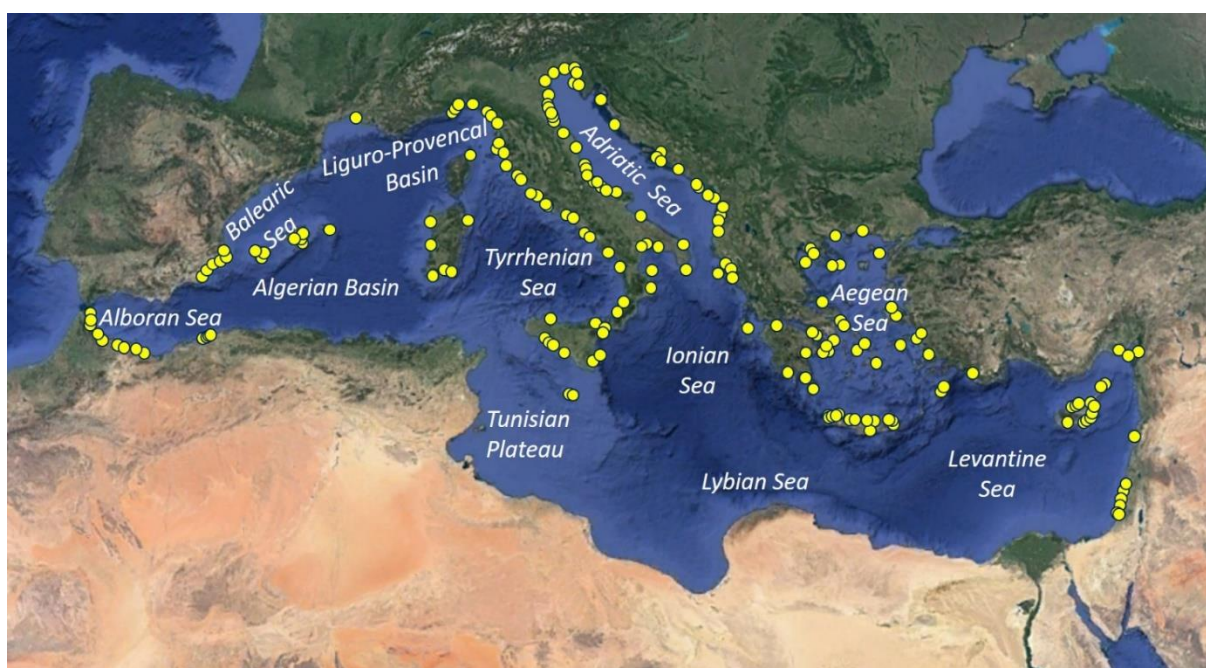


Fig. 3. Geographical distribution of macro-MBL collections in the Mediterranean Sea and its main sub-basins. Yellow dots indicate the beaches where single or multiple surveys were realized.

The amount and the composition of MBL can vary over geographical scales and reflects the geomorphological and hydrographical characteristics of the coast (Ansari and Farzadkia, 2022). Different criteria drive the selection of the surveyed areas according to the objectives of each monitoring campaign. The majority of the analysed projects consider specific factors and often aim at covering different exposure to natural and anthropogenic drivers of litter deposition (e.g., Prevenios et al., 2018). Among these factors, the most represented are i) distance from urban areas, harbour, river outflow, shipping lane; ii) prevailing meteorological conditions (e.g., sea currents and winds); iii) beach characteristics (e.g., length, orientation, substrate and slope); iv) usage of the beach and/or of the surrounding area (e.g., tourism, agriculture, industrial activities). Sometimes, surveyed areas distribution is arbitrarily selected to uniformly cover the whole length of an investigated coastline (e.g., Asensio-Montesinos et al., 2019a). Only a few studies (17%)

1 focus on natural reserves and marine protected areas (e.g., Giovacchini et al., 2018; de Francesco et al.,
2 2021). This is possibly due to the MSFD and UNEP guidelines suggesting that survey activities should be
3 conducted so as not to impact on any endangered or protected species (Cheshire et al., 2009; Galgani et al.,
4 2013).

5 Beach typology information is provided in 59% of the publications ([Table 1 and Table S3](#)). Nevertheless, only
6 one third of the publications follow the Bathing Area Registration and Evaluation (BARE) system (see chapter
7 9 in Williams and Micallef, 2009) that classifies coastal sites into four beach types (remote, rural, village,
8 urban), according to the difficulty of access, level of coastal occupation and community services. Thus, criteria
9 are not completely homogenous. Several authors, in fact, only indicate the main destination of the area, e.g.,
10 touristic/non-touristic (Lagalbauer et al., 2014); very touristic/low touristic/remote (Grelaud and Ziveri,
11 2020); industrial/agricultural/urban/rural (Gundogdu and Cevik, 2019); or its geographical characteristics,
12 such as wetland (Alshawafi et al., 2017; Battisti et al., 2019), river estuary (e.g., Romiti et al., 2021). As stated
13 above, a few publications report more detailed information about beach selection, including parameters such
14 as minimum length or width, slope range, access, presence of vegetation, dunes, road, fence or other
15 anthropogenic structures (e.g., Vlachogianni et al., 2020).

16 As for shoreline characteristics, 78% of analysed papers report information about the coastal type ([see Table
17 1 and Table S3](#)). As expected, sandy beaches represent the majority of the surveyed sites. However, rocky
18 areas, cobbles and pebbles beaches, and less frequently cliffs and artificial coasts, have been also studied.

25 3.4. Sampling methodologies and data analysis

26 Depending on how they are designed and realized, MBL counts and collections can reflect the presence,
27 amounts and types of marine debris, and the long-term balance between inputs (e.g., land-based sources,
28 storms, tides) and export (e.g., degradation, clean-up) over a coastal area (Portman and Brennan, 2017).
29 However, the evaluation of fluxes between beaches and nearshore marine waters is usually difficult. Surveys
30 mostly represent a valid tool for tracking minor changes in overall abundance and accumulation rates, as well
31 as for monitoring evident changes in the composition of litter (Galgani et al., 2013). These goals imply an
32 appropriate logical temporal and spatial organization of surveys and the choice of criteria (e.g., parameters,
33 standard sampling units, replications) that allow the inter-comparison between observations collected by
34 different operators in different moments over the same (or different) areas.

35 The sampling strategies to assess the occurrence of MBL include a wide range of methodologies/approaches,
36 depending on many factors, including the main goal of a given study (Velandar and Mocogni, 1999; Romiti et
37 al., 2021) and the costs associated to the application of different protocols. The latter include, for example,
38 labour in different phases of monitoring, equipment, specialized personnel and other running costs (MSFD,
39 2013).

40 [Table 2](#) summarizes surveys information for scientific collections analysed in this study. The compiled
41 information shows a large variety of applied methodologies and criteria. Firstly, the standard unit (*i.e., the
42 fixed section (length) of beach from which measurements of litter number of items, weight or volume are
43 made periodically - Galgani et al., 2013*), is usually very different among the collections. Only for half of them
44 (29 of 58) it consisted of a 100 m long coastal sector. Some authors opted for 50 m or for full length of the
45 surveyed beach (about 18%). Other sampling activities (20%), indeed, opted for quadrats instead of linear
46 transects. Again, quadrats dimensions vary from site to site ([Table 2](#)). The remaining publications present
47 customized sampling units due to specific research interests or to the absence of standardized protocols (e.g.,
48 for studies dating to the '80s). The different strategies, of course, imply manual collections of litter items
49 during some surveys (about 80 %), and only visual inspection during others (about 20%). In some cases (20%)
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1 the observer recorded litter data whilst moving along separated transects parallel to the coastline (usually 5
2 m wide) in order to cover the entire usable beach, from the shoreline up to its landward limits (e.g., Asensios
3 Monteisons, 2019a). Conversely, 30% of the surveys were performed along transects normal to the coastline,
4 from the strandline to the back of the beach (e.g., Grelaud and Ziveri, 2020).

5 Another important difference lies in the size of MBL surveyed during monitoring activities. Different
6 definitions can be found in the analysed publications. Generally, there are no upper size limits and classes of
7 items. On the other hand, the lower limit of detection varies considerably from survey to survey. A few
8 collections (10%) set the MBL size lower limit at 0.5 cm (e.g., Taibi et al., 2021). As generally recommended,
9 most of the analysed collections (41%) opt indeed for a lower limit of 2.5 cm in the longest dimension (e.g.,
10 Giovacchini et al., 2018). This ensures, for example, the inclusion of caps and lids and cigarette butts in any
11 counts (Galgani et al., 2013). Other surveys use different lower limits (28%), such as 2 cm (12%) or 1 cm (5%),
12 or do not provide clear information about size limits (21%).
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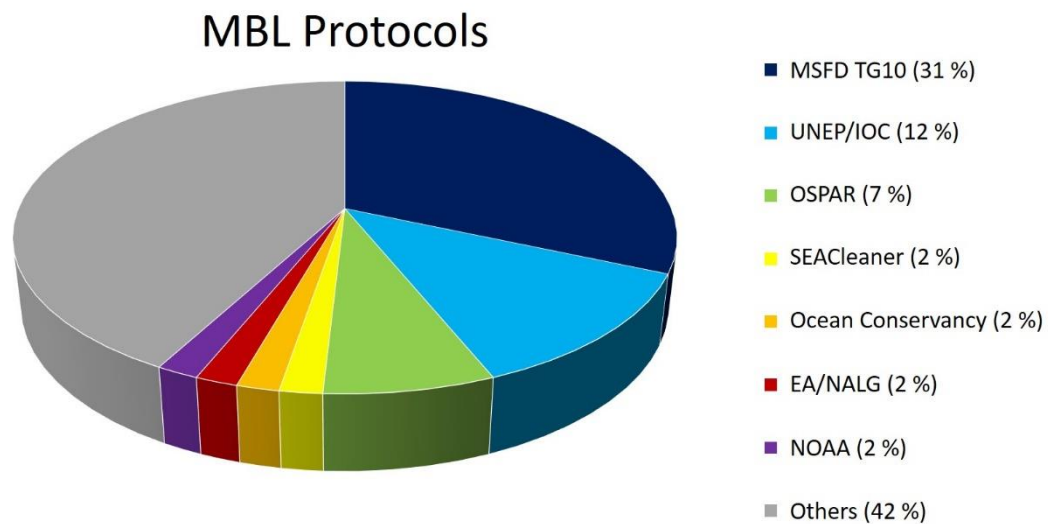


Fig. 4. Percentage distribution of sampling protocols used in MBL data collections indexed in Scopus.

All these differences are the results of the application of different protocols providing specific guidelines for MBL sampling. Figure 4 summarizes information reported in Table 2 through the percentage distribution of the official protocols applied in the analysed studies. Since their release in 2013, the guidelines suggested by the MSFD technical group on marine litter (MSFD Technical Support group on marine litter, 2013) represent the most used protocol (31%). These recommendations are based on the OSPAR Commission Guidelines for Monitoring Marine Litter on the Beaches in the OSPAR Maritime Area (OSPAR, 2010a), UNEP Operational Guidelines for Comprehensive Beach Litter Assessment (Cheshire et al., 2009) and the NOAA Marine Debris Shoreline Survey Field Guide (Opfer et al., 2012).

Similar differences can be found in the existing approaches for identification and classification of information about the observed MBL typology. Most of the analysed studies firstly group MBL items into macro-categories according to the basic material they are made of (e.g., plastics, wood, metal, glass, paper, organic matter, etc.), then divide them into specific typologies. Although several detailed international guidelines exist (e.g., EA/NALG, 2000; Cheshire et al., 2009; OSPAR, 2010a; Opfer et al., 2012; Galgani et al., 2013), scientists are often dealing with specific interests and needs, so they categorize litter into personalized groups (e.g., Battisti et al., 2019; Fanini and Guittard, 2021) or combine different litter classification schemes (Asensio-Montesinos et al., 2021a). Sometimes, very detailed information, such as the specific type or even brand of single items, are also used to support specific analyses, such as source attribution (e.g., Golik and

1 Gertner, 1992; Renzi and Blaskovic, 2018). Among the selected publications, the most used classification
2 scheme (31%) is the master list suggested by MSFD GES Technical Subgroup on Marine Litter (Galgani et al.,
3 2013). This reference list was developed as part of a technical (non-legally binding) guidance document with
4 recommendations for monitoring marine litter in accordance with the MSFD (Portmann and Brennan, 2017).
5 It considers 213 categories referring to MBL grouped into eight material classes and permits to assign each
6 litter item to a standard General Code (G-Code). However, several studies that use G-code only consider a
7 subset of 165 relevant categories, among the 213 available for MBL classification, excluding categories for
8 micro-litter (i.e., G103-123) or other residual types of items which are not applicable to monitoring marine
9 macro-litter on beaches. G-code was derived in order to move towards harmonised monitoring, but different
10 lists have been and are still being used in parallel, such as the OSPAR Items List for 100-metre sampling, which
11 contains 121 MBL categories divided into 11 groups of classes, or the UNEP/IOC items list, which includes 77
12 typologies grouped in 10 material classes.
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15 Furthermore, different studies count and report MBL amount in different ways. The unit in which litter is
16 assessed range among number, weight or volume. A combination of these units can be also used (see [Table](#)
17 [3](#)). Generally, count of items is recommended as the easiest way to assess its presence along the coastline.
18 The assessment of weight of litter, instead, can be more difficult because it is dependent on MBL items
19 conditions (e.g., wet or dry, covered or plenty of sand or gravel, too big for being weighted on site; Jambeck
20 and Farfour 2011). The assessment of the volume of litter is also problematical because it depends on the
21 level of compression of the litter involved. Among the analysed collections, just two studies do not consider
22 items abundance preferring to assess MBL through its weight (Alshawafi et al., 2017) and percentage
23 coverage (Mo et al., 2021). Conversely, 33 studies report only MBL abundance, while the others focus on
24 abundance and weight or a combination of different parameters including abundance (19 and 5 documents,
25 respectively). It is also interesting to notice that 19% of the available documents do not mention if/how MBL
26 was removed during/after beach [surveys](#), or they adopt methodologies that include visual census without
27 waste removal (Merlino et al., 2021). Moreover, only six studies declare a direct participation of volunteers.
28 However, as stated above, non-scientific initiatives [usually have no fixed end-date and](#) are characterized by
29 a massive use of websites and outreach reports, thus appearing in scientific publications only at later stages,
30 frequently after several years, [when scientific conclusions can be finally retrieved \(Schneider et al., 2018\)](#).
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34 Whatever is the applied collection methodology, scientists usually convert their abundance, weight or
35 volume information into density, opting for per beach length unit (m) rather than per beach area unit (m²) in
36 order to facilitate the comparability of MBL on a temporal, local, or global level (Papachristopoulou et al.,
37 2020). Still, differences exist among available studies estimating density per m (m²) or 100 m (100 m²) of
38 beach face length ([Table 3](#)). Most of the analysed studies reporting MBL abundance densities express them
39 in items/m² or items/100 m² (66%), while a lower percentage of collections use per length units (21%) or both
40 (13%). Statistical analyses are always very useful when processing and interpreting these data. [Table 3](#) shows
41 that a variety of univariate and multivariate analyses have been used in the selected publications. Opting for
42 a specific statistical tool seems to be generally driven by the research objectives more than the typology of
43 the collected dataset. Mathematical formulas and coefficients can be used for providing an evaluation of
44 beach quality, for example through common shared indices, and litter sources. The clean cost index, for
45 example, provides an aggregate indicator that translates the quality of the beaches in terms of potential and
46 direct damage to the health of marine organisms, and it results very useful for spatial (e.g., beaches with
47 different characteristics) and temporal (e.g., seasonal or interannual) comparisons. Nevertheless, only 34%
48 of the analysed studies reports this kind of information using different indices, i.e., clean cost index (15
49 studies), litter grade (3), pollution density index (1), index of environmental spoil (1), accumulation index (1),
50 Chao's Sørensen index (1).
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Finally, it is noteworthy that 81% of available Scopus indexed documents deal, somehow, with litter source analysis. To this goal, a variety of methods have been used, from simple counts of items believed to originate from a given source to more complex mathematical methods, such as the Matrix Scoring Technique [proposed](#) by Tudor and Williams (2004) and further developed by ARCADIS (Van Acoleyen et al., 2013) for use with the OSPAR MBL data. This technique considers the level of likelihood of the origin of each litter item evaluating all potential sources. A qualitative score (e.g., from "very likely" to "very unlikely" or "not considered") is assigned to each potential source and then translated to a scoring system (i.e., using weighted numerical values). The attribution of likelihoods is based on the type of litter, distance from each source, impact of a specific activity in the area and any other local factor that can affect litter contribution (Veiga et al., 2016).

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Table 2. Surveys information for scientific collections identified by ID numbers, as in [Table 1](#).

| ID | Sampling unit | Transect details | Units | Tot area or length | Methodology | MBL size | Protocol | MBL classification |
|----|----------------------|---|-------|------------------------|----------------------|----------|----------------------------------|---|
| 1 | customized | area included the zone between the low and high water marks | 7 | 1500 m ² | visually | > 2 cm | NA | type (e.g., metal, plastic, glass, paper) |
| 2 | customized | area included the zone between the low and high water marks | 1 | NA | manually | > 2 cm | NA | type (e.g., metal, plastic, glass, paper) |
| 3 | customized | 5 m wide, normal to the coastline, from the waterline to the back of the beach | 472 | NA | visually or manually | > 1 cm | NA | NA |
| 4 | customized | normal to the coastline, from the waterline to the back of the beach | 64 | NA | manually | > 2 cm | NA | 7 groups (plastics, wood, Styrofoam, fishing gear, glass, metal, other) |
| 5 | 50 m | | NA | NA | visually | NA | NA | 7 groups (plastic, metal, glass, paper, wood, cloth, other) |
| 6 | 100 m | | 15 | 1500 m | manually | NA | EA/NALG | 45 litter types |
| 7 | customized | 2 m wide, normal to the shoreline, 15 m apart, upper few cm | NA | NA | manually | > 0.1 cm | NA | 7 groups (plastics, wood, metal, glass, paper, organic matter, other) |
| 8 | full beach | | NA | NA | manually | ≥ 1 cm | NA | 8 groups (glass, plastic, paper, aluminum, other metals, rope, building materials, other materials) |
| 9 | 2 x 2 m ² | | 153 | 612 m ² | visually | > 2.5 cm | NA | 165 categories in 8 groups (G-code) |
| 10 | 50 m | parallel to the shoreline | 6 | 300 m | manually | ≥ 2 cm | UNEP/IOC (Cheshire et al., 2009) | 59 categories in 8 groups |
| 11 | 100 m | 12 m wide | 146 | 33,790 m ² | visually | NA | UNEP/IOC (Cheshire et al., 2009) | 87 categories |
| 12 | customized | normal to the coastline, from the action of waves limitation up to territorial plants | NA | 209,220 m ² | manually | > 2.5 cm | NA | 10 groups about material (plastic, nylon, fibres, polystyrene, glass, metal, paper, wood, synthetic material, cigarette butts/package) and 11 about usage (drink packaging, food packaging, |

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| | | | | | | | | packaging, fishing material, rope, recreational, cleaning supplies, medical supplies, cigarette, cloth/shoes, others) |
| 13 | 100 m | parallel to the shoreline | 3 | 300 m | manually | NA | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 14 | 0.4 x 0.4 m ² | 5 m apart, from the back of the beach to the waterline, 10 cm depth | 75 | 12 m ² | sieved by a 2mm mesh | > 2.5 cm | NA | 165 categories in 8 groups (G-code) |
| 15 | 100 m | | NA | NA | manually | > 2 cm | MSFD TG10 | 8 groups (cloth, foamed plastic, glass and ceramics, metal, paper and cardboard, plastic, rubber, wood) |
| 16 | customized | parallel to the coastline, from the shoreline to the dune habitats | NA | NA | manually | > 0.5 cm | OSPAR | 6 groups (plastic, polystyrene, glass, paper, mixed, other) |
| 17 | 100 m | perpendicular to the coastline, from waterline to the back of the beach | 144 | 595,200 m ² | manually | > 2.5 cm | MSFD TG10 | 213 categories in 8 groups (G-code) |
| 18 | 100 m | perpendicular to the coastline, from sea line to back dune's woody vegetation | 15 | 112,500 m ² | manually | > 2 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 19 | 100 m | perpendicular to the coastline, from waterline to the back of the beach | 33 | 32,154 m ² | manually | NA | SEACleaner Protocol | 33 categories in 9 groups (plastic, polystyrene, wood, foam/sponge, textiles, multimaterial, rubber, glass, metal) |
| 20 | 100 m | perpendicular to shoreline, 50 m apart | 180 | 33,200 m ² | manually | all items | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 21 | 100 m | | NA | NA | manually | > 2 cm | NOAA (Ioakeimidis et al., 2016) | 6 categories (plastic, lumber and paper, cloth and fabric, glass, metal, rubber) |
| 22 | 100 m | parallel to shoreline, 5 m apart between shoreline and beach landward | 17 | 108,051 m ² | manually | > 2.5 cm | UNEP/IOC (Cheshire et al., 2009) | 7 groups (artificial polymers, rubber, textile, paper, metal, wood, glass and ceramics) |
| 23 | 50 m | perpendicular to the beach, from waterline to the back of the beach | 10 | 12,000 m ² | manually | > 2.5 cm | UNEP/IOC (Cheshire et al., 2009) | 76 categories in 9 groups |
| 24 | 0.5 x 0.5 m ² | 10 m wide along shoreline | 30 | 7.5 m ² | manually | NA | NA | fragments, pellets, films |

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| 25 | 100 m | parallel to shoreline, 5 m apart from the strandline to the beach landward | 56 | 408,204 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 26 | 100 m | perpendicular to the coast, no more than 50 m apart | 192 | 19,200 m | manually | > 0.4 cm | MSFD TG10 | 59 categories in 10 groups |
| 27 | 100 m | | 21 | 5476 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 9 groups (G-code) |
| 28 | full beach | | NA | 20,980 m ² | manually | NA | Ocean Conservancy | 41 categories (Ocean Conservancy) |
| 29 | full beach | | NA | 31,461 m ² | vessel-based photography | ≥ 2.5 cm | MSFD TG10 | 213 categories in 8 groups (G-code) |
| 30 | 50 m | | 104 | 26,000 m ² | manually | > 2.5 cm | MSFD TG10 | 8 groups (OSPAR, 2010a) |
| 31 | 100 m | perpendicular to the beach, from waterline to the back of the beach | 147 | 14,700 m | manually | > 2.5 cm | OSPAR | 9 groups (artificial polymer materials, rubber, cloth/textile, paper/cardboard, processed/worked wood, metal, glass/ceramics, unidentified and chemicals) |
| 32 | 2 x 2 m ² | random quadrats | 120 | 480 m ² | manually | all items | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 33 | 0.5 x 0.5 m ² | perpendicular to the coastline, 20 m apart along highest waterline; 5 cm depth | 110 | 27.5 m ² | sieved by a 1mm mesh | ≥ 0.5 cm | NA | fragments, pellets, films |
| 34 | 1 x 1 m ² | high strandline, mid line, backshore line; 5 cm depth | 117 | 117 m ² | sieved by a 5 mm mesh | > 2.5 cm | adapted from Losh (2015), Frias et al. (2018) | 5 groups of plastics (filament, film, foam, fragments, pellets) |
| 35 | 2 x 2 m ² | random quadrats | 180 | 720 m ² | manually | > 2.5 cm | OSPAR, UNEP/MAP | 6 groups about material (plastic, polystyrene, glass, paper, aluminum, mixed waste) and 5 for usage (containers, fishing and boating, food and beverage, packaging, other) |
| 36 | 100 m | perpendicular to the coast, 50 m apart | 10 | 24,000 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 37 | 100 m | parallel to coastline, 5 m apart | NA | 201,686 m ² | visually | > 2.5 cm | UNEP/IOC, NOAA, OSPAR | 116 categories in 8 groups (UNEP code) |
| 38 | 100 m | parallel to coastline, 5 m apart | NA | 201,700 m ² | visually | > 2.5 cm | EA/NALG, UNEP/IOC, | 129 categories in 8 groups (UNEP code) |

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|----|--------------------------|--|----|------------------------|-----------|-----------|----------------------------------|--|
| | | | | | | | OSPAR, NOAA | |
| 39 | 100 m | 10 m wide along shoreline | 3 | 2800 m ² | manually | > 0.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 40 | 100 m | perpendicular to the coastline, at least 50 m apart | 62 | 113,780 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories (G-code) in 3 groups (single-use plastics, non-single use plastics, non-plastics) |
| 41 | 4 x 4 m ² | random quadrats, with nested 1 x 1 m ² plots | 22 | 352 m ² | visually | > 2.5 cm | NA | 213 categories in 8 groups (G-code) |
| 42 | full beach | | NA | 15,000 m ² | manually | > 3 cm | NA | fishing lines and hooks |
| 43 | 100 m | perpendicular to the coastline, from the strandline to the back of the beach | 18 | 16,500 m ² | manually | all items | MEDPOL | 11 categories (plastic, rubber, textile, glass, ceramics, processed wood, metal, paper, sanitary waste, medical waste, paraffin/wax) |
| 44 | 100 m | 10 m wide | 4 | 4000 m ² | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 45 | 0.3 x 0.3 m ² | random quadrats, from the shoreline to the base of the dune; 10 cm depth | 9 | 0.81 m ² | box corer | > 3 cm | allometric models | plastic items |
| 46 | 100 m | parallel to the shoreline, 5 m apart | NA | 63,645 m ² | visually | > 2.5 cm | UNEP/MAP | 207 categories in 9 groups (UNEP code) |
| 47 | full beach | wet beach, dry beach, fore dune, hind dune | NA | 48,000 m ² | manually | container | Poeta et al. 2015 | 3 groups (plastic, glass, aluminium) in 5 categories of shape/volume (small bottles (< 1.5 l), large bottles (≥ 1.5 l), tanks (≥ 5 l), jars (0.3-1 l), cans (0.3–0.5 l)) |
| 48 | 400 m | | NA | 400 m | manually | > 2.5 cm | NA | 2 groups (traws, wraps litter) |
| 49 | 100 m | 20 m wide | 19 | 38,000 m ² | manually | NA | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 50 | 0.2 x 0.2 m ² | parallel to the coastline, 30 m from the water's edge, 50 m apart | 32 | 1.28 m ² | manually | > 2.5 cm | customized | vegetal wrack and plastic litter (Hanke et al., 2013) |
| 51 | 100 m | parallel to shoreline, from the water line to the beach backshore | 10 | NA | manually | > 5.0 cm | UNEP/IOC (Cheshire et al., 2009) | 5 groups (bottles, bags, packaging, tyres, other) |
| 52 | 100 m | from the landward beach limit to the shoreline, garbage bins | 5 | 500 m | manually | > 2.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |

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| 53 | 100 m | from the landward beach limit to the shoreline, garbage bins | 8 | 800 m | Manually | > 0.5 cm | MSFD TG10 | 165 categories in 8 groups (G-code) |
| 54 | full beach | perpendicular to the coastline, 2 m apart from the strandline to the backshore area | 35 | 73,451 m ² | Manually | > 0.5 cm | Williams and Tudor, 2001 | 183 categories |
| 55 | 90 m | along the dunes, backdunes, channels in wetland | 13 | 1170 m | sieve by a 8 mm mesh | > 1 cm | customized | total litter and expanded polystyrene subcategory (EPS) |
| 56 | 3 x 3 m ² | | 100 | 900 m ² | unmanned aerial vehicle, visually | > 0.5 cm | OSPAR | 43 tipologies divided in 6 groups (fragments, containers, packaging, sanitary, clothing, others) |
| 57 | 100 m | perpendicular to the coastline, from the tide line to the back border of the beach | 2 | 1600 m ² | manually/visually | > 5 cm | NA | 28 categories |
| 58 | Customized | | NA | 3000 m ² | Manually | > 2.5 cm | NA | 7 groups (bottle cap, cotton buds, expanded polystyrene, cigarette butts, generic fragments, bottles, other containers) |

Table 3. MBL collection details for surveys identified by ID numbers, as in [Table 1](#).

| ID | Measurements | Total litter | Litter density estimation | litter removal | Volunteers participation | Statistical analysis | indices | Sources analysis |
|----|----------------------|--------------------------|--|----------------|--------------------------|--|---|------------------|
| 1 | abundance | | g cm ⁻³ | | | | | yes |
| 2 | abundance | | g cm ⁻³ | | | | | yes |
| 3 | abundance | 17,355 items | | yes | | Wilcoxon test, Duncan test | | yes |
| 4 | abundance and weight | | g m ⁻¹ | yes | | | | yes |
| 5 | abundance | | items 100 m ⁻² | | | | pollution density index, index of environmental spoil | |
| 6 | abundance | | | yes | | PCA, cluster analysis | | yes |
| 7 | abundance and weight | | items m ⁻¹ | yes | | PCA, multivariate analysis, redundancy analysis, univariate analysis of variance | | yes |
| 8 | abundance | 110,423 items | | yes | yes | R-mode factor analysis, cluster analysis | | yes |
| 9 | abundance | | | | | Shapiro–Wilk test, Kruskal–Wallis test, generalized linear mixed-effects model, Pearson correlation test | | yes |
| 10 | abundance and weight | 5,870 items | items m ⁻² g m ⁻² | yes | | multidimensional scaling | clean coast index | |
| 11 | abundance | 69,122 items | items 100 m ⁻² | yes | | | | yes |
| 12 | abundance | 1,445 items | items 100 m ⁻² | yes | | | | yes |
| 13 | abundance | 39,972 items | items 100 m ⁻¹ | yes | | PERMANOVA | | |
| 14 | abundance and weight | 12,263 items 0.734 kg | items m ⁻² g m ⁻² | yes | | | | |
| 15 | abundance and weight | | items m ⁻² g m ⁻² | yes | | multivariate adaptive regression splines | clean coast-index | yes |
| 16 | abundance | 6,100 items | | yes | | | | yes |
| 17 | abundance and weight | 41,617 items | items 100 m ⁻¹ items m ⁻² | yes | | PCA, Kruskal-Wallis test, Dunn's test, PCA with Varimax rotation, PERMANOVA, Kaiser-Meyer-Olkin test | | yes |
| 18 | abundance | 31,739 items | items m ⁻¹ | yes | | PERMANOVA, SIMPER | | yes |
| 19 | abundance | 34,027 items | items m ⁻² | yes | yes | PCA, cluster analysis | clean coast index | yes |

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|----|------------------------------|--------------------------|--|-----|-----|---|-----------------------|-----|
| 20 | abundance | 70,581 items | items 100 m ⁻¹ items m ⁻² | yes | | | clean coast index | yes |
| 21 | weight | 12.855 kg | | yes | yes | PCA, cluster analysis | | yes |
| 22 | abundance and weight | 8,021 items 198 kg | items m ⁻² g m ⁻² | yes | | | | yes |
| 23 | abundance | 2,502 items | items m ⁻² | yes | | PERMANOVA, regression analysis, Shannon's diversity index, UPGMA sorting, Bray-Curtis index, SIMPER | clean coast index | yes |
| 24 | abundance and weight | 1,345 items 13.491 kg | items m ⁻² items kg ⁻¹ | yes | | PERMANOVA, Bray-Curtis index, SIMPER | | |
| 25 | abundance | 21,943 items | items 100 m ⁻¹ items m ⁻² | yes | | | clean coast index | yes |
| 26 | abundance | | items 100 m ⁻¹ | yes | | PERMANOVA, SIMPER | | yes |
| 27 | abundance | 3,305 items | items m ⁻² | yes | | Pearson's Chi-Square test | clean coast index | |
| 28 | abundance | 7,658 items | | yes | yes | | | yes |
| 29 | abundance | 17,620 items | items 100 m ⁻¹ | | | regression analysis | | yes |
| 30 | abundance and weight | 59,556 items 697 kg | items m ⁻² items m ⁻¹ g m ⁻² g m ⁻¹ | yes | | | | yes |
| 31 | abundance | 162,320 items | items m ⁻² | yes | | accumulation rate | accumulation index | yes |
| 32 | abundance | 585 items | items m ⁻² | yes | | univariate statistics, SIMPER, PCA | | yes |
| 33 | abundance, weight, colour | 356 items | items m ⁻² g m ⁻² | yes | | Mann-Whitney test, Kruskal-Wallis test, NDWD test | | yes |
| 34 | abundance and weight | 1,424 items | items m ⁻² g m ⁻² | yes | | Mann-Whitney test, Kruskal-Wallis test, PERMANOVA, PCA, Bray-Curtis index | | yes |
| 35 | abundance | 1,492 items | items m ⁻² | yes | | PCA, Mann-Whitney test | | yes |
| 36 | abundance | 3,321 items | items 100 m ⁻¹ items m ⁻² | yes | | cluster analysis | | yes |
| 37 | abundance | 10,101 items | items m ⁻² | | | multivariate analysis, nMDS, cluster analysis | litter grade | yes |
| 38 | abundance | 30,941 items | items m ⁻² | | | nMDS, PCA, cluster analysis | litter grade | yes |
| 39 | abundance and weight | 6,010 items | items m ⁻² | yes | | | clean coast index | yes |

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|----|--|--|--|-----|-----|---|------------------------------------|-----|
| 40 | abundance | 37,991 items | items 100 m ⁻¹ items m ⁻² | yes | yes | cluster analysis | | yes |
| 41 | percentage coverage | | | | | Kruskal-Wallis test, PERMANOVA, diachronic analyses, Shapiro-Wilk test, Levene test | | |
| 42 | abundance, length of the lines, density of hooks | 243 fishing lines 88 skeins 33 hooks | cm m ⁻² mg m ⁻² items ha ⁻¹ | yes | | | | |
| 43 | abundance and weight | 133,4 kg | items m ⁻² | yes | | | clean coast index | |
| 44 | abundance | 11,024 items | items m ⁻² | yes | | | clean coast index | yes |
| 45 | abundance and weight | | | yes | | nMDS | | |
| 46 | abundance | 31,571 items | items 100 m ⁻¹ items m ⁻² | yes | | Kolmogorov–Smirnov test, Bartlett’s test, Tukey’s test, ANOVA | litter grade, clean coast index | yes |
| 47 | abundance | 2,177 containers | items 100 m ⁻² | | | | chao’s sørensen index | |
| 48 | abundance, shape, colour | | items m ⁻¹ | yes | | Spearman rank correlation | | yes |
| 49 | abundance and weight | 7,839 items 231 kg | items m ⁻² g m ⁻² | yes | | | clean coast index | yes |
| 50 | abundance and weight | | items m ⁻² | yes | | Mann-Whitney test, Pearson or Spearman correlation test | | |
| 51 | abundance | 14,537 items | items m ⁻² | yes | | | | yes |
| 52 | abundance and weight | 2,324 items 105.44 kg | items m ⁻² g m ⁻² | yes | | one-way ANOVA | clean coast index | yes |
| 53 | abundance and weight | 10,717 items 229.29 kg | items m ⁻² g m ⁻² | yes | | one-way ANOVA | clean coast index | yes |
| 54 | abundance | 2,410 items | items 100 m ⁻¹ items m ⁻² | yes | | nMDS, cluster analysis, Bray–Curtis index | clean coast index | yes |
| 55 | abundance | 2,120 items | | yes | | Kruskall-Wallis test, Mann-Whitney test | | |
| 56 | abundance and colour | 332 items | | | yes | Kendall’s coefficient of concordance | | yes |
| 57 | abundance and weight | 810 items 1641.25 kg | | | | | | yes |
| 58 | abundance and weight | 6,700 items, 10.717 kg | | yes | | | | |

4. Discussion

The assessment of litter composition is one of the great strengths of coastal monitoring. A detailed assessment can provide information on potential harm to the environment and, potentially, on the source of the litter found (Ansari and Farzadkia, 2022). To this aim, the assessment and analysis of MBL must follow commonly agreed methodologies in order to provide results which are comparable over larger regions and different periods.

The Final Report “Guidance on Monitoring of Marine Litter in European Seas” (Galgani et al., 2013), realized by MSFD TSG-ML, provides recommendations and information needed for an effective monitoring of the MBL. Much of the information included is taken from some of the most comprehensive and useful overviews for monitoring methods on the coast, i.e., the UNEP (Cheshire et al., 2009), the OSPAR (OSPAR, 2010a), and the NOAA (Opfer et al., 2012) guidelines.

MSFD TSG-ML suggests that when designing marine litter surveys, it is necessary to differentiate between standing-stock surveys, where the total load of litter is assessed during a one-off count, and the assessment of accumulation and loading rates during regularly repeated surveys of the same stretch of beach with initial and subsequent removal of litter (Galgani et al., 2013). The amount of litter arriving on a given length of beach over a given period of time can be expressed as [unit quantity of litter] per [unit length of beach] per [unit time]. Conversely, the amount of material standing on the beach is usually determined as [unit quantity of litter] per [unit length of beach] (Cheshire et al., 2009). The accumulation periods should be approximately of the same length. To this aim, the minimum sampling frequency of a given beach should be annually, roughly on the same day each year. Ideally, beach site should be surveyed every three months through seasonal collections at regular intervals in time. Thus, at least four surveys per year (i.e., in spring, summer, autumn and winter) are recommended by MSFD (Galgani et al., 2013).

Nevertheless, the information reported in the analysed Scopus indexed publications shows that MBL monitoring activities are typically conducted over a limited and short period of time (e.g., covering two years or less, or even including only single-day surveys). This implies that only few studies can effectively assess the temporal variation in the amount of litter present on a given beach, or several beaches. Additionally, also the collections characterized by seasonal repetitions are significantly affected by seasonal variation that might partly mask long-term variability (Schulz et al., 2013). Still, the surveys should be repeated on exactly the same site (Galgani et al., 2013) that should not be subject to any other litter collection activity except the monitoring survey; alternatively, the frequency and timing of the other beach cleaning (e.g., those carried out every morning at dawn during the summer to please tourists) should be well known and documented such that their influence on the litter flux rates can be determined. This information is generally missing in the analysed scientific production. All these aspects make rather impossible the estimation of trends. As a consequence, in the existing literature the assessment of the MBL temporal and spatial variability in a surveyed areas is generally obtained through the comparison with data published in previous studies. Normalized variables (e.g., density and/or weight per m²) help this task but a direct comparison often neglects that different collections may have been realized taking advantage of different protocols and guidelines.

The selection of a specific costal sites for the monitoring activities is another factor that can significantly influence the comparability of the achieved results. Geomorphological and sedimentary characteristics, river presence, meteo-oceanographic regimes, litter exposure (e.g., urban sites, rural coasts, marine protected area), demographic and geographical conditions, main beach usage (i.e., recreational, fishing, surfing, boat access) should be always considered and reported. Unfortunately, only few publications clearly define these characteristics.

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Even more important is the choice of the MBL sampling unit. Both MSFD and OSPAR guidelines suggest a minimum length of 100 m, which can be reduced to 50 m for heavily littered beaches, and a repetition of at least two sections on the same beach. Even though most of the considered studies follow these recommendations, a large number of collections opted for quadrats (of different sizes) and customized criteria, instead of linear transects (Table 2). Inhomogeneity also exists in the use of transects which are carried out parallel rather than perpendicular to the coast, at a different distance between each other, and covering determined or variable beach width. Moreover, several studies do not report at all this information, providing quantitative litter estimation that can be hardly comparable to other collections. This issue sums to the fact that the observed data are sometimes expressed per beach length unit (m) rather than per beach area unit (m²) in different MBL collections. Although per length unit can be more easily related to floating litter fluxes washed ashore, most of the analysed studies do report MBL densities per beach area. However, when the whole width of the beach is sampled, for equal litter counts, one must consider that per area densities can increase as the width of the beach decreases, resulting in higher values for narrow beaches data, and viceversa (Prevenios et al., 2018). Additionally, these quantitative estimates can refer to abundance or weight (or even to volume in a few cases). This generates additional problems because estimations obtained through weight-based surveys (in kg) cannot be directly compared to those based on the number of items. A comparison between the two methodologies can be attempted when estimates of average weights of the counted litter items are known. However, this would not be always possible since litter items of the same materials occur on beaches in a wide range of sizes and weights.

Furthermore, even though no upper size limits are applied to litter recorded on beaches, the analysed studies shows that lower size limits can be very different from survey to survey. Actually, the lower limit should be determined by the possibility of detection by the naked eye, thus being dependent on the surveyor's visual perception (eyesight) and on the conspicuousness of the MBL items. This actually depends on litter abundance, size, colour and form. The macro-MBL size lower limit is often identified around 0.5 cm. However, it is doubtful that such small items can be monitored effectively during beach surveys in different locations and by differently experienced personnel, e.g., trained scientists, volunteers (OSPAR, 2010a). In this sense, a lower limit of 2.5 cm in the longest dimension seems more recommendable (Galvani et al., 2013), as applied by the majority of the Mediterranean studies carried out in the recent years.

The attribution of litter categories also plays an important role, as do different interpretations of monitoring guidance. Generally, MBL composition is estimated by grouping the items into different predetermined categories to favour comparability and compatibility of available observations. However, our analysis shows that this classification is usually based on different codes in the existing literature (see Table 2). Different classification schemes allow to report a different detail of information, from the raw material to the specific type, or even brand, of single items, that can differently support additional litter analyses, such as source attribution (e.g., Golik and Gertner, 1992; Renzi and Blaskovic, 2018). The available observations can still be considered as a valuable proxy for the amount of litter present in a coastal environment. However, comparing information collected in different areas/seasons/years, by different groups, is generally difficult and represents a limit to the identification of priorities for action or effectiveness of mitigation measures. Moreover, MBL data are usually not accompanied by proper uncertainties, so that they deserve a careful metadata interpretation to evaluate their accuracy and reliability.

Nevertheless, several analysed studies also attempted of determine top litter items over a specific region. Unfortunately, the top items calculation modes were often different among surveys, as well as the category lists and the top items ranking length. Consequently, even if data enable the ranking of items according to their abundance, in many cases they cannot be directly compared with rankings from other collections due

1 to the different monitoring techniques used. These issues add to the above-mentioned differences in MBL
2 sampling and reporting of the results, so that the aggregation of different studies proved to be often
3 unfeasible. Thus, obtaining comparable data and sampling strategies remains a priority to provide the basis
4 for reliable litter abundance rankings and previous studies integration. The final report of the EU ARCADIS
5 project, for example, lists the top fifteen MBL items for the Mediterranean Sea from 33 OSPAR screenings
6 indicating plastic cutlery/trays/straws as the dominant fraction (17%), followed by cigarette butts (14%),
7 plastic caps/lids (14%) and plastic drink bottles (12%) (Van Acoleyen et al., 2013). The report on Marine Litter
8 Assessment in the Mediterranean, instead, states that the main groups of items found on beaches in the
9 Mediterranean are sanitary items (mostly cotton bud sticks), cigarette butts and cigar tips, as well as
10 packaging items and bottles, all likely related to coastal-based tourism and recreation (UNEP/MAP MEDPOL,
11 2015). Several other surveys confirm that smoking related waste are a significant problem in the
12 Mediterranean, representing the most frequent items found on beaches, with abundances ranging from 35-
13 62% of the total items recorded (e.g., Martinez-Ribes et al., 2007; UNEP/MAP MEDPOL, 2011; Öko-Institut,
14 2012). Items related to uncontrolled discharges and inadequately managed waste also represent an
15 important problem in several Mediterranean countries (Makhoukh, 2012; Jambeck et al., 2015; UNEP/MAP
16 MEDPOL, 2015).

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22 The identification of the MBL source and pathway is another crucial step in determining the actions and
23 measures to reduce its impact in a given area. The above-mentioned protocols provide useful master lists
24 that relate item categories with potential sources of litter. Nonetheless, source identification is relatively
25 easy only for some items (e.g., fish box/nets; glass bottle in proximity of a beach bar). For the majority of
26 items, especially those fragmented or altered by long stay in the natural environment, it is much more
27 difficult to assign a source with a robust level of accuracy. The analysed Scopus dataset shows that several
28 methodological approaches have been used to determine where litter is coming from, but few information
29 is provided about value and limitations of the attribution of sources per type of item. Several studies, for
30 example, assume that all occurring items from a certain category originate from a particular source/pathway.
31 This is based on the assumption that certain items are typically or widely used by particular sectors (e.g.,
32 fishing, shipping, medical) and are conventionally released into the environment via specific pathways. Such
33 approaches can provide a preliminary indication of contribution of key sources. On the other hand, they
34 dismiss potential contributions from other sources (and/or pathways) and the importance of multiple
35 sources. To overcome these issues, several analysed studies do made use of attribution of sources based on
36 statistical techniques, such as the Matrix Scoring Technique that includes the likelihood criteria. Nonetheless,
37 a reliable likelihood analysis always deserves an accurate knowledge of the survey sites and its surroundings
38 to determine in advance a number of possible local and regional litter sources (e.g., tourism, fishing, shipping,
39 general littering, inadequate waste management, etc.). This information is rarely reported in the analysed
40 Scopus indexed literature.

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49 Another important issue is represented by litter removal during/after beach surveys, and the consequent
50 waste treatment. Actually, removal of litter should be carried out during monitoring activities. This is
51 important to ensure better accuracy of reporting, to allow the comparison of litter accumulation over time,
52 to reduce MBL impact on the ecosystems, and to leave a clean coastline to beach users (Galgani et al., 2013).
53 It is also very important limiting the quantity of sand and living organisms that could be removed during
54 manual/mechanical MBL collections (Zielinski et al., 2019). Among the analysed studies, several collections
55 rely on counting litter items without removing them from the coastline, or do not mention if/how MBL was
56 removed during/after beach surveys. When litter is removed, only a few documents provide details about
57 the expected impact of beach cleaning as a factor for loss of species abundance and changes to the beach
58 natural conditions (Defeo et al., 2009; Del Vecchio et al., 2017; Schneider et al., 2018). Information about the
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specific efforts to recruit, and train, field staff, are also missing in almost all of the analysed studies. Nevertheless, this is essential to ensure data quality and prevent environment damages, especially when citizen and volunteers are involved in the beach monitoring activities.

Finally, waste disposal and treatment also represent a tackling issue that deserves careful specific discussion. Almost no information about waste treatment is available in the analysed publications, so that it is impossible to evaluate the potential efforts in terms of reuse, recycle, energy recovery and landfill. Conversely, previous projects demonstrated that, even if challenging, it is possible to reuse or recycle macro-litter, such as fish nets, metals, lead line, polystyrene buoys (e.g., Northwest Straits Foundation, 2015; National Fish and Wildlife Foundation, 2016; Iñiguez et al., 2016), turn them into art (Olive Ridley Project, 2017), or use them to recover energy (Iñiguez et al., 2016).

5. Conclusions

In the last decades scientists, citizens and policy makers recognized MBL as a serious issue for coastal ecosystems, human health and economical activities. Due to high anthropogenic pressure, intensive economical exploitation and slow turnover of its waters, the Mediterranean Sea is particularly vulnerable to this problem. A systematic review of current literature concerning MBL monitoring strategies along its coasts shows that increasing efforts have been realized to monitor, study, and clean-up shorelines in the last two decades.

Despite the ongoing efforts and initiatives to harmonize MBL monitoring over Mediterranean coasts, the heterogeneity of the source data still represents a major challenge in terms of standardization of the data management procedures and of data comparison. The presented extensive literature review points out that these studies were generally characterized by significant differences in timing and frequency of the surveys, in litter sampling and classification methodologies, as well as in the analysis and presentation of the collected data. A large number of protocols for MBL monitoring exists, originally developed from a number of campaigns over a thirty-year period. On the impulse of the MSFD, they are on the way to evolve into a standardized monitoring tool. However, this task has not been achieved yet. Current MBL monitoring activities follow different approaches, which somehow rely on the UNEP/IOP, OSPAR, NOAA and MSFD guidelines, but they still miss harmonization in the strategy of survey, as well as in the analysis and presentation of the collected observations. The choice of a particular type of survey often depends on the objectives of the assessment, on the magnitude of the pollution, and on the typology on the coastline. Thus, the comparison of MBL data between different assessment programmes is still difficult due to the use of different methods, different spatial and temporal scales, different size scales of litter items, and different lists or categorisation of litter items recorded on beaches. Consequently, even though some similarities can be found, giving indications for intercomparison studies, the lack of standardization of the monitoring protocols limit the integration of MBL data and the efforts to provide a pan-Mediterranean MBL temporal and spatial analysis.

Nevertheless, the monitoring of MBL in Mediterranean Sea can be still considered a valid and important tool for coastal environment conservation. Pressing research needs must be addressed as soon as possible. First of all, it is essential to make easier a direct comparison of information collected by different groups/initiatives and over different countries. Adopting consistent and harmonised criteria and methodological standards, would ensure consistency of data and the possibility of meaningful comparison. To this goal, coordination at a regional/national/Mediterranean level is urgently needed. Differently, an efficient monitoring system for MBL cannot be permanently maintained. In this framework, it would be warmly welcome the improvement

1 and support to the use of shared platforms (e.g., EMODnet) to group and disseminate MBL observations, so
2 to homogenize the processing of datasets based on different protocols and reference systems, and facilitate
3 the identification of gaps and hindrances. Surveys and clean-up activities carried out along the southern
4 Mediterranean coasts, for example, are rarely reported in scientific publications, but they do exist.
5 Strengthening international collaborations across the Mediterranean would help this process. Similarly, it is
6 necessary to favour synergy between marine litter research in all environmental compartments (i.e., seafloor,
7 water column, sea surface, coast, biota). Making the data collected, raw and processed, public and easily
8 accessible, and having them available not only to the scientific community but also to policy makers and
9 stakeholders, would be important as well. To this goal, the shared methods of spatial and temporal
10 monitoring of Mediterranean beaches should be easy to follow by both scientists and volunteers. Collections
11 that can be conducted as part of the normal human presence in the marine environment, such as beach
12 clean-ups, appear interesting cost effective and environmentally friendly solutions (Schneider et al., 2018).
13 Involving more trained volunteers in MBL monitoring (e.g., through associations, schools, Citizen Science
14 projects) would, at the same time, arise the ecological awareness and support the scientific monitoring
15 efforts. This could also help create a communication channel between the world of research and policy
16 makers.
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22 Actually, a consistent increase in MBL monitoring efforts does not necessarily mean a significant reduction
23 of the overall stock of MBL. A growing and much larger amount of new waste, in particular plastics, is added
24 to the marine environment every year (Jambeck et al., 2015). A drastic input reduction is indeed necessary
25 to tackle the challenge of MBL effectively. Recognize the degree of waste decomposition, and improve its
26 treatment, as well as identifying the main sources is essential to design effective intervention strategies to
27 prevent litter from entering the marine environment. The allocation of likelihoods of MBL (e.g., through the
28 Matrix Scoring Technique) can provide a useful picture of sources and their relative importance in a certain
29 area. However, a number of indispensable factors must be enquired to characterize correctly a given region
30 (local topography and geography, human activities and their intensity, proximity to potential litter sources
31 or pathways). Again, this process needs shared guidelines, central coordination, local knowledge and
32 stakeholders' collaboration.
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38 In conclusion, despite the progresses recently achieved through several research activities, there is still an
39 urgent need to promote broad international collaboration in order to improve and harmonize scientific and
40 politics efforts to produce quality, open, and comparable MBL data over the Mediterranean basin (Sanchez-
41 Simon et al., 2022). Quality science is fundamental to engage and inform policy makers, stakeholders and
42 society to the goal of implementing effective measures, actions and regulations to tackle the challenging MBL
43 threats.
44
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46
47

48 **References**

- 49 Addamo, A.M., Laroche, P., Hanke, G., 2017. Top marine beach litter Items in Europe: a review and synthesis
50 based on beach litter data. In: JRC Technical Report EUR 29249 EN.
- 51
52 Addamo, A.M., Brosich, A., Chaves, M.D.M., Giorgetti, A., Hanke, G., Molina, E., Vinci, M., 2018. Marine litter
53 baselines: challenges and hindrances in compiling the first pan-European beach litter database. In: JRC
54 Technical Reports. JRC112895.
- 55
56
57 Afghan, A., Cerrano, C., Luzi, G., Calcinai, B., Puce, S., Pulido Mantas, T., Roveta, C., Di Camillo, C.G., 2020.
58 Main Anthropogenic Impacts on Benthic Macrofauna of Sandy Beaches: A Review J. Mar. Sci. Eng. 8, 405.
59
60
61
62
63
64
65

- 1 Agamuthu, P., Mehran, S.B., Norkhairah, A., Norkhairiyah, A., 2019. Marine debris: a review of impacts and
2 global initiatives. *Waste Manag. Res.* 37 (10), 987–1002.
- 3 Alshawafi, A., Analla, M., Alwashali, E., Aksissou, M., 2017. Assessment of marine debris on the coastal
4 wetland of Martil in the North-East of Morocco. *Mar. Pollut. Bull.* 117, 302–310.
- 5
6 Angiolillo, M., and Fortibuoni, T. 2020. Impacts of marine litter on mediterranean reef systems: From shallow
7 to deep waters. *Front Mar Sci* 7, 581966.
- 8
9 Ansari, M., and Farzadkia, M. 2022. Beach debris quantity and composition around the world: A bibliometric
10 and systematic review. *Mar. Pollut. Bull.* 178, 113637.
- 11
12 Arthur, C., Baker, J., Bamford, H. Eds., 2009. Proceedings of the International Research Workshop on the
13 Occurrence, Effects and Fate of Microplastic Marine Debris, Tacoma, WA, USA, September 9-11, 2008. NOAA
14 Technical Memorandum NOS-OR&R-30.
- 15
16 Asensio-Montesinos, F., Anfuso, G., Randerson, P., Williams, A.T., 2019a. Seasonal comparison of beach litter
17 on Mediterranean coastal sites (Alicante, SE Spain). *Ocean Coast. Manag.* 181.
- 18
19 Asensio-Montesinos, F., Anfuso, G., Williams, A.T., 2019b. Beach litter distribution along the western
20 Mediterranean coast of Spain. *Mar. Pollut. Bull.* 141, 119–126.
- 21
22 Asensio-Montesinos, F., Anfuso, G., Aguilar-Torrelo, M.T., Oliva Ramirez, M., 2021a. Abundance and
23 Temporal Distribution of Beach Litter on the Coast of Ceuta (North Africa, Gibraltar Strait). *Water* 13, 2739.
- 24
25 Asensio-Montesinos, F., Anfuso, G., Williams, A.T., Sanz-Lazaro, C., 2021b. Litter behaviour on Mediterranean
26 cobble beaches, SE Spain. *Mar. Pollut. Bull.* 173, 113106.
- 27
28 Aulicino, G., Cotroneo, Y., Lacava, T., Sileo, G., Fusco, G., Carlon, R., Satriano, V., Pergola, N., Tramutoli, V.,
29 Budillon, G., 2016. Results of the first wave glider experiment in the southern Tyrrhenian Sea. *Adv. Oceanogr.*
30 *Limnol.* 7, 16–35.
- 31
32 Aulicino, G., Cotroneo, Y., Ruiz, S., Sanchez Roman, A., Pascual, A., Fusco, G., Tintoré, J., Budillon, G., 2018.
33 Monitoring the Algerian Basin through glider observations, satellite altimetry and numerical simulations
34 along a SARAL/AltiKa track. *J. Mar. Syst.* 179, 55–71.
- 35
36 Aydın C, Güven O, Salihoğlu B, et al., 2016. The influence of land use on coastal litter: An approach to identify
37 abundance and sources in the coastal area of Cilician Basin, Turkey. *Turkish J. Fish. Aquat. Sci.* 16, 29–39.
- 38
39 Battisti, C., Poeta, G., Pietrelli, L., Acosta, A.T., 2016. An unexpected consequence of plastic litter clean-up on
40 beaches: Too much sand might be removed. *Environ. Pr.* 18, 242–246.
- 41
42 Battisti, C., Kroha, S., Kozhuharova, E., De Michelis, S., Fanelli, G., Poeta, G., Pietrelli, L., Cerfolli, F., 2019.
43 Fishing lines and fishhooks as neglected marine litter: first data on chemical composition, densities, and
44 biological entrapment from a Mediterranean beach. *Environ. Sci. Pollut. Res.* 26, 1000–1007.
- 45
46 Benaissa, N., Haddad, F.Z., Taleb Bendiab, A.A., Bensahla-Talet, L., Hamou, A., Dimache, A., 2018. A
47 preliminary study on macro-litter pollution on beaches along Ain El Turk Bay. *Geo-Eco-Mar.* 27.
- 48
49 Bowman, D., Manor-Samsonov, N., Golik, A., 1998. Dynamics of litter pollution on Israeli Mediterranean
50 beaches: a budgetary, litter flux approach. *J. Coast. Res.* 14 (2), 418–432.
- 51
52 Bozzeda, F., Zangaro, F., Colangelo, M.A., Pinna, M., 2021. Relationships between size and abundance in
53 beach plastics: A power-law approach. *Mar. Pollut. Bull.* 173, 113005.
- 54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
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45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Brouwer, R., Hadzhiyska, D., Ioakeimidis, C., Ouderdorp, H., 2017. The social costs of marine litter along European coasts. *Ocean Coast. Manag.* 138, 38-49.

Camedda, A., Coppa, S., Palazzo, L., et al., 2021. Characterization and Assessment of Micro and Macroscopic Litter in Sardinian Beaches (Western Mediterranean Sea). *Water Air Soil Pollut.* 232, 41.

Cesarano, C., Aulicino, G., Cerrano, C., Ponti, M., Puce, S., 2021. Scientific knowledge on marine beach litter: A bibliometric analysis. *Mar. Pollut. Bull.* 173, 113102.

Cesarini, G., Cera, A., Battisti, C., Taurozzi, D., Scalici, M., 2021. Is the weight of plastic litter correlated with vegetal wrack? A case study from a Central Italian beach. *Mar. Pollut. Bull.*, 171, 112794.

Cheshire, A., Adler, E., Barbieri, J., Cohen, Y., Evans, S., Jarayabhand, S., Jetric, L., Jung, R.T., Kinsey, S., Kusui, T., Lavine, I., Manyara, P., Oosterbaan, L., Pereira, M. A., Sheavly, S., Tkalin, A., Varadarajan, S., Wenneker, B., Westphalen, G., 2009. UNEP/IOC guidelines on survey and monitoring of marine litter. <https://wedocs.unep.org/20.500.11822/13604>.

Cole, M., Lindeque, P., Halsband, C., Galloway, T.S., 2011. Microplastics as contaminants in the marine environment: a review. *Mar. Pollut. Bull.* 62, 2588–2597.

Compa, M., Ventero, A., Iglesias, M., Deudero, S., 2018. Ingestion of microplastics and natural fibres in *Sardina pilchardus* (Walbaum, 1792) and *Engraulis encrasicolus* (Linnaeus, 1758) along the Spanish Mediterranean coast. *Mar. Pollut. Bull.* 128, 89–96.

Cotroneo, Y., Celentano, P., Aulicino, G., Perilli, A., Olita, A., Falco, P., Sorgente, R., Ribotti, A., Budillon, G., Fusco, G., Pessini, F., 2021. Connectivity analysis applied to mesoscale eddies in the Western Mediterranean basin. *Remote Sens.* 13, 4228.

Cózar, A., Sanz-Martín, M., Martí, E., I., J., G, G.-, Ubeda, B., Gálvez, J.Á., Irigoien, X., Duarte, C.M., 2015. Plastic accumulation in the Mediterranean Sea. *PLoS One* 10.

Cresta, E., Battisti, C., 2021. Anthropogenic litter along a coastal-wetland gradient: Reed-bed vegetation in the backdunes may act as a sink for expanded polystyrene. *Mar. Pollut. Bull.* 172, 112829.

de Francesco, M.C., Carranza, M.L., Stanisci, A., 2018. Beach litter in Mediterranean coastal dunes: an insight on the Adriatic coast (central Italy). *Rend. Lincei Sci. Fis. Nat.* 29, 825e830.

de Francesco, M.C., Carranza, M.L., Varricchione, M., Tozzi, F.P., Stanisci, A., 2019. Natural protected areas as special sentinels of littering on coastal dune vegetation. *Sustain. Times* 11, 1e16.

Defeo, O., McLachlan, A., Schoeman, D.S., Schlacher, T.A., Dugan, J., Jones, A., Lastra, M., Scapini, F., 2009. Threats to sandy beach ecosystems: a review. *Estuar. Coast. Shelf Sci.* 81(1), 12.

Del Vecchio, S., Junker, T., Carboni, M., Acosta, A.T.R., 2017. Linking plant communities on land and at sea: the effects of *Posidonia oceanica* wrack on the structure of dune vegetation. *Science* 84, 30–36.

Dugan, J.E., Hubbard, D.M., Mccrary, M., Hubbard, D.M., Mccrary, M.D., Pierson, M.O., 2003. The response of macrofauna communities and shorebirds to macrophyte wrack subsidies on exposed sandy beaches of southern California. *Estuar Coast Shelf Sci.* 58:25, 40.

EA/NALG, 2000. In: *Assessment of Aesthetic Quality of Coastal and Bathing Beaches. Monitoring Protocol and Classification Scheme.* Environment Agency and The National Aquatic Litter Group, London, p. 15.

Ertas, A., 2021a. Assessment of origin and abundance of beach litter in Homa Lagoon coast, West Mediterranean Sea of Turkey Estuarine. *Estuar. Coast. Shelf Sci.* 249, 107114.

1 Ertas, 2021b. Assessment of beach litter pollution in Adana Akyatan Lagoon Coast of the East Mediterranean.
2 Mar. Pollut. Bull. 163, 111943.

3 European Commission, 2018a. Communication from the Commission: A European Strategy for Plastics in a
4 Circular Economy—Strategy, COM/2018/028.

5
6 European Commission, 2018b. Commission Staff Working Document Impact Assessment. Reducing Marine
7 Litter: action on single use plastics and fishing gear. Brussels, 28.5.2018, SWD(2018) 254, pp.76.

8
9 Fanini, L., Guittard, A., 2021. On single use plastic straws: Pre-ban findings on touristic beaches in Crete. Mar.
10 Pollut. Bull. 171, 112790.

11
12 Figueiredo Nascimento, S., Cuccillato, E., Schade, S., Guimarães Pereira, A. Joint Research Centre, 2016.
13 Citizen Engagement in Science and Policy-Making. Scientific and Technical Research Reports, Publications
14 Office of the European Union, EUR 28328 EN.

15
16 Forleo, M.B. and Romagnoli, L., 2021. Marine plastic litter: public perceptions and opinions in Italy. Mar.
17 Pollut. Bull. 165, 112160.

18
19 Fortibuoni, T., Ronchi, F., Macic, V., Mandic, M., Mazziotti, C., Peterlin, M., Prevenios, M., Prvan, M.,
20 Somarakis, S., Tutman, P., Varezic, D.B., Virsek, M.K., Vlachogianni, T., Zeri, C., 2019. A harmonized and
21 coordinated assessment of the abundance and composition of seafloor litter in the Adriatic-Ionian
22 macroregion (Mediterranean Sea). Mar. Pollut. Bull. 139, 412e426.

23
24 Fossi, M.C., Bains, M., Panti, C., Baulch, S., 2018. Impacts of Marine Litter on Cetaceans: A Focus on Plastic
25 Pollution, in: Fossi, M.C., Panti, C. (Eds), Marine Mammal Ecotoxicology, Academic Press, pp. 147-184, ISBN
26 9780128121443.

27
28 Fossi, M.C., Vlachogianni, T., Galgani, F., Innocenti, F.D., Zampetti, G., Leone, G., 2019. Assessing and
29 mitigating the harmful effects of plastic pollution: the collective multi-stakeholder driven Euro-
30 Mediterranean response. Ocean Coast Manag. 184, 105005.

31
32 Frias, J., Pagter, E., Nash, R., O'Connor, I., Carretero, O., Filgueiras, A., et al., 2018. Standardised protocol for
33 monitoring microplastics in sediments. JPI-OCEANS, BASEMAN, Deliverable 4.2.
34 <https://repository.oceanbestpractices.net/handle/11329/1206>. Accessed 20 January 2021.

35
36 Gabrielides, G.P., Golik, A., Loizides, L., Marino, M.G., Bingel, F., Torregrossa, M.V., 1991. Man-made garbage
37 pollution on the Mediterranean coastline. Mar. Pollut. Bull. 23, 437–441

38
39 Galgani, F., Hanke, G., Werner, S., Oosterbaan, L., Nilsson, P., Fleet, D., McKinsey, S., Thompson, R.,
40 VanFraneker, J., Vlachogianni, T., Scoullou, M., Mira, V.J., Palatinus, A., Matiddi, M., Maes, T., Korpinen, S.,
41 Budziak, A., Leslie, H., Gago, J., Liebezeit, G., 2013. MSFD technical group on Marine Litter, Guidance on
42 Monitoring of Marine Litter in European Seas. JRC Scientific and Policy rep483-490orts, SJRC83985, EUR
43 26113 ENI, SBN 978-92-79-32709-4. ISSN: 1831-9424.

44
45 Gall, S.C., Thompson, R.C., 2015. The impact of debris on marine life. Mar. Pollut. Bull. 92, 170–179.

46
47 Giovacchini, A., Merlino, S., Locritani, M., Stroobant, M., 2018. Spatial distribution of marine litter along
48 Italian coastal areas in the Pelagos sanctuary (Ligurian Sea—NW Mediterranean Sea): A focus on natural and
49 urban beaches. Mar. Poll. Bull. 130, 140–152.

50
51 Gjyli, L., Vlachogianni, T., Kollitari, J., Matta, G., Metalla, O., Gjyli, S., 2020. Marine litter on the Albanian
52 coastline: baseline information for improved management. Ocean Coast Manag. 187, 105108.

53
54 Golik, A., Gertner, Y., 1992. Litter on the Israeli coastline. Mar. Environ. Res. 33 (1), 1–15.

55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
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46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Gönülal, O., Öz, I., Güreşen, S.O., Öztürk, B., 2016. Abundance and composition of marine litter around Gökçeada Island (Northern Aegean Sea), *Aquat. Ecosyst. Health Manag.* 19:4, 461-467.

Grelaud, M., Ziveri, P., 2020. The generation of marine litter in Mediterranean island beaches as an effect of tourism and its mitigation. *Sci. Rep.* 10, 20326.

Gundogdu, S., Cevik, C., 2019. Mediterranean dirty edge: High level of meso and macroplastics pollution on the Turkish coast. *Environ. Pollut.* 255, 113351.

Hanke, G., Galgani, F., Werner, S., Oosterbaan, L. et al., 2013. In: Hanke, G., Werner, S., Galgani, F., Veiga, J.M., Ferreira, M. (Eds.), *Guidance on Monitoring of Marine Litter in European Seas*. Edition: EUR – Scientific and Technical Research Series – ISSN 1831-9424 (Online). Publications Office of the European Union, Luxembourg. ISBN: 978-92-79-32709-4.

Hanke, G., Walvoort, D., van Loon, W., Addamo, A.M., Brosich, A., del Mar Chaves Montero, M., Molina Jack, M.E., Vinci, M., Giorgetti, A., 2019. *EU Marine Beach Litter Baselines*. Publications Office of the European Union, Luxembourg. EUR 30022 EN

Hidalgo-Ruz, V., Thiel, M., 2015. The contribution of citizen scientists to the monitoring of marine litter. In: Bergmann, M., Gutow, L., Klages, M. (Eds.), *Marine anthropogenic litter*. Springer, Berlin, pp. 433–451.

Iniguez, M.E., Conesa, J.A., Fullana, A., 2016. Marine debris occurrence and treatment: a review. *Renew. Sust. Energ. Rev.* 64, 394–402.

Jambeck, J.R., Farfour, W.M., 2011. *Characterization of Individual Marine Debris Items by Mass*. 5th International Marine Debris Conference, April 2011, Honolulu, HI.

Jambeck, J.R., Geyer, R., Wilcox, C., Siegler, T.R., Perryman, M., Andrady, A., Law, K.L., 2015. Plastic waste inputs from land into the ocean. *Science* 347 (6223), 768–771.

Karkanorachaki, K., Kiparissis, S., Kalogerakis, G.C., Yiantzi, E., Psillakis, E., Kalogerakis, N., 2018. Plastic pellets, meso- and microplastics on the coastline of Northern Crete: distribution and organic pollution. *Mar. Pollut. Bull.* 133, 578–589.

Katsanevakis, S., 2015. Illegal immigration in the eastern Aegean Sea: a new source of marine litter. *Mediterr. Mar. Sci.* 16(3), 605-608.

Keswani, A., Oliver, D.M., Gutierrez, T., Quilliam, R.S., 2016. Microbial hitchhikers on marine plastic debris: human exposure risks at bathing waters and beach environments. *Mar. Environ. Res.* 118, 10–19.

Kiessling, T., Gutow, L., Thiel, M., 2015. Marine litter as habitat and dispersal vector. *Mar. Anthropol. Litter.* 141–181.

Kordella S., Geraga M., Papatheodorou G., Fakiris E., M. Mitropoulou I., 2013. Litter composition and source contribution for 80 beaches in Greece, Eastern Mediterranean: A nationwide voluntary clean-up campaign, *Aquat. Ecosyst. Health Manag.* 16 (1), 111-118.

Laglbauer, J.L.B., Franco-Santos, R.M., Andreu-Cazenave, M., Brunelli, L., Papadatou, M., Palatinus, A., Grego, M., Deprez, T., 2014. Macrodebris and microplastics from beaches in Slovenia. *Mar. Pollut. Bull.* 89, 356–366

Law, K.L., 2017. Plastics in the marine environment. *Annu. Rev. Mar. Sci.* 9, 205–229.

Li, W.C., Tse, H.F., Fok, L., 2016. Plastic waste in the marine environment: a review of sources, occurrence and effects. *Sci. Total Environ.* 566–567, 333–349.

1 Loizidou, X.I., Loizides, M.I., Orthodoxou, D.L., 2018. Persistent marine litter: small plastics and cigarette butts
2 remain on beaches after organized beach cleanups. *Environ. Monit. Assess.* 190 (7), 414.

3 Losh, S., 2015. A Proposed Method to Analyze Meso-And Microplastic Pollution on Beaches in Oregon. Honor.
4 Baccalaureate Sci. Environ. Sci. Oregon State University, University Honors College, Oregon, USA.

5
6 Lucrezi, S. and Digun-Aweto, O., 2020. "Who wants to join?" Visitors' willingness to participate in beach litter
7 clean-ups in Nigeria. *Mar Pollut. Bull.* 155, 111167.

8
9 Makhoukh, M., 2012. Pollution par les déchets solides en Algérie. Stratégie de gestion Intégrée des zones
10 côtières en Algérie? Bilan et diagnostic. MATE-PAP RAC 2012, 42 pages.

11
12 Mandić, M., Gvozdenović, S., Peraš, I., Ivanović, A., Malovražić, N., 2021. Quantification and Classification of
13 Beach Litter in Montenegro (South-East Adriatic Sea). In: Joksimović, D., Đurović, M., Zonn, I.S., Kostianoy,
14 A.G., Semenov, A.V. (eds) *The Montenegrin Adriatic Coast. The Handbook of Environmental Chemistry*, 110,
15 Springer, Cham.

16
17
18 Martinez-Ribes, L., Basterretxea, G., Palmer, M., Tintoré, J., 2007. Origin and abundance of beach debris in
19 the Balearic islands. *Sci. Mar.* 71, 305–314.

20
21
22 Maziane, F., Nachite, D., Anfuso, G., 2018. Artificial polymer materials debris characteristics along the
23 Moroccan Mediterranean coast. *Mar. Pollut. Bull.* 128, 1-7.

24
25 MedSeaLitter EU Project, 2019. Available online: <https://medsealitter.interreg-med.eu>

26
27 Merlino, S., Paterni, M., Berton, A., Massetti, L., 2020. Unmanned aerial vehicles for debris survey in coastal
28 areas: long-term monitoring programme to study spatial and temporal accumulation of the dynamics of
29 beached marine litter. *Remote Sens.* 12, 1260.

30
31 Merlino, S., Paterni, M., Locritani, M., Andriolo, U., Gonçalves, G., Massetti, L., 2021. Citizen Science for
32 Marine Litter Detection and Classification on Unmanned Aerial Vehicle Images. *Water* 13(23), 3349.

33
34 Mghili, B., Analla, M., Aksissou, M., Aissa, C., 2020. Marine debris in Moroccan Mediterranean beaches: An
35 assessment of their abundance, composition and sources. *Mar. Pollut. Bull.* 160, 111692.

36
37
38 Mo, A., D'Antraccoli, M., Bedinia, G., Ciccarelli, D., 2021. The role of plants in the face of marine litter invasion:
39 A case study in an Italian protected area. *Mar. Pollut. Bull.* 169, 112544.

40
41 Mocos, M., Zamora Martinez, I., Zubak, I., 2019. Is central Croatian Adriatic Sea under plastic attack?
42 Preliminary results of composition, abundance and sources of marine litter on three beaches. *Rend. Lincei*
43 *Sci. Fis. Nat.* 30, 797e806.

44
45 Mocos, M., Rokov, T., Zubak Čižmek, I., 2020. Monitoring and analysis of marine litter in Vodenjak cove on Iž
46 Island, central Croatian Adriatic Sea. *Rend. Lincei Sci. Fis. Nat.* 31, 905–912.

47
48 MSFD GES Technical Subgroup on Marine Litter, 2013. Guidance on monitoring of marine litter in European
49 seas. MSFD GES Technical Subgroup on Marine Litter 2013.

50
51
52 Munari, C., Corbau, C., Simeoni, U., Mistri, M., 2016. Marine litter on Mediterranean shores: analysis of
53 composition, spatial distribution and sources in north-western Adriatic beaches. *Waste Manag.* 49, 483–490.

54
55 Munari, C., Scoponi, M., Mistri, M., 2017. Plastic debris in the Mediterranean Sea: types, occurrence and
56 distribution along adriatic shorelines. *Waste Manag.* 67, 385e391.

57
58
59 Nachite, D., Maziane, F., Anfuso, G., Williams, A.T., 2019. Spatial and temporal variations of litter at the
60 Mediterranean beaches of Morocco mainly due to beach users. *Ocean Coast Manag.* 179, 1e14.

61
62
63
64
65

1 National Fish and Wildlife Foundation, 2016. Fishing for energy. Available at:
2 http://www.nfwf.org/fishingforenergy/Documents/ffe_factsheet_16-0329.pdf

3 Northwest Straits Foundation, 2015. Shallow water legacy derelict net removal from high priority areas of
4 puget sound. Available at: [http://www.nwstraitsfoundation.org/download/shallow-water-legacy-derelict-](http://www.nwstraitsfoundation.org/download/shallow-water-legacy-derelict-net-removal-fromhigh-priority-areas-of-puget-sound)
5 [net-removal-fromhigh-priority-areas-of-puget-sound](http://www.nwstraitsfoundation.org/download/shallow-water-legacy-derelict-net-removal-fromhigh-priority-areas-of-puget-sound).
6

7 Öko Institute, 2012. Study on Land sourced Litter in the Marine Environment. Review of sources and
8 literature. Öko Institut report, 128 pages.
9

10 Olive Ridley Project, 2017. News from the field. Available at:

11
12 Novi, L., Bracco, A., Falasca, F., 2021. Uncovering marine connectivity through sea surface temperature. Sci.
13 Rep. 11, 8839.
14

15
16 Opfer, S., Arthur, C., Lippiatt, S., 2012. NOAA Marine Debris Shoreline Survey Field Guide. US National Oceanic
17 and Atmospheric Administration Marine Debris Program.
18

19 OSPAR, 2010a. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR area, Edition 1.0, ISBN
20 90 3631 973 9., 16 pp.
21

22 OSPAR, 2010b. OSPAR Beach Questionnaire 2010.012.
23

24 Özden, Ö., Yıldırım, S., Fuller, W.J., Godley, B.J., 2021. Anthropogenic marine litter on the north coast of
25 Cyprus: insights into marine pollution in the eastern Mediterranean. Mar. Pollut. Bull. 165, 112167.
26

27 Papachristopoulou, I., Filippides, A., Fakiris, E., Papatheodorou, G., 2020. Vessel based photographic
28 assessment of beach litter in remote coasts. A wide scale application in Saronikos Gulf, Greece. Mar. Pollut.
29 Bull. 150, 110684.
30

31
32 Pasternak, G., Zviely, D., Ribic, C.A., Ariel, A., Spanier, E., 2017. Sources, composition and spatial distribution
33 of marine debris along the Mediterranean coast of Israel. Mar. Pollut. Bull. 114 (2), 1036–1045.
34

35
36 Petry, M.V., Benemann, V.R., 2017. Ingestion of marine debris by the White-chinned Petrel (*Procellaria*
37 *aequinoctialis*): is it increasing over time off southern Brazil? Mar. Pollut. Bull. 117 (1–2), 131–135.
38

39 Pinardi, N., and Masetti, E. 2000. Variability of the large scale general circulation of the Mediterranean Sea
40 from observations and modelling: a review. *Palaeo* 158.
41

42 Poeta, G., Battisti, C., Acosta, A.T.R., 2014. Marine litter in Mediterranean sandy littorals: spatial distribution
43 patterns along Central Italy coastal dunes. Mar. Pollut. Bull. 89, 168–173.
44

45 Poeta, G., Conti, L., Malavasi, M., Battisti, C., Acosta, A.T.R., 2016a. Beach litter occurrence in sandy littorals:
46 the potential role of urban areas, rivers and beach users in central Italy. *Estuar. Coast. Shelf Sci.* 181, 231–
47 237.
48

49
50 Poeta, G., Battisti, C., Bazzichetto, M., Acosta, A.T.R., 2016b. The cotton buds beach: marine litter assessment
51 along the Tyrrhenian coast of central Italy following the marine strategy framework directive criteria. Mar.
52 Pollut. Bull. 113, 266–270.
53

54
55 Portman, M.E., Brennan, R.E., 2017. Marine litter from beach-based sources: case study of an Eastern
56 Mediterranean coastal town. *Waste Manag.* 69, 535-544.
57

58 Prevenios, M., Zeri, C., Tsangaris, C., Liubartseva, S., Fakiris, E., Papatheodorou, G., 2018. Beach litter
59 dynamics on Mediterranean coasts: distinguishing sources and pathways. Mar. Pollut. Bull. 129 (2), 448–457.
60
61
62
63
64
65

- 1 Renzi, M., Blašković, A., 2018. Litter and microplastics features in table salts from marine origin: Italian versus
2 Croatian brands. *Mar. Pollut. Bull.* 135, 62-68.
- 3 Rodil, I.F., Harris, L.R., Lucrezi, S. and Cerrano, C., 2022. Sandy Beach Management and Conservation: The
4 Integration of Economic, Social and Ecological Values. In *Sandy Beaches as Endangered Ecosystems*, 251-294,
5 CRC Press.
- 6
7 Romiti, F., Pietrangeli, E., Battisti, C., Carpaneto, G.M., 2021. Quantifying the entrapment effect of
8 anthropogenic beach litter on sand-dwelling beetles according to the EU Marine Strategy Framework
9 Directive. *J. Insect Conserv.* 25, 441–452.
- 10
11 Schneider, F., Parsons, S., Clift, S., Stolte, A., McManus, M., 2018. Collected marine litter - a growing waste
12 challenge. *Mar. Pollut. Bull.* 128, 162–174
- 13
14 Schulz, M., Neumann, D., Fleet, D., Matthies, M., 2013. A multi-criteria evaluation system for marine litter
15 pollution based on statistical analyses of OSPAR beach litter monitoring time-series, *Mar. Environ. Res.* 92,
16 61-70.
- 17
18 Shiber, J.G., 1979. Plastic pellets on the coast of Lebanon. *Mar. Pollut. Bull.* 10, 28–30.
- 19
20 Shiber, J.G., 1982. Plastic pellets on Spain's Costa del Sol beaches. *Mar. Pollut. Bull.* 13, 409-412.
- 21
22 Shiber, J. G., 1987. Plastic pellets and tar on the beaches of the Mediterranean coast of Spain. *Mar. Pollut.*
23 *Bull.* 18, 84-86.
- 24
25 Shiber, J.G., Barrales-Rienda, J.M., 1991. Plastic pellets, tar and megalitter on Beirut beaches, 1977-1988.
26 *Environ. Pollut.* 71, 17-30.
- 27
28 Silc, U., Kūzmic, F., Cakovic, D., Stesevic, D., 2018. Beach litter along various sand dune habitats in the
29 southern Adriatic (E Mediterranean). *Mar. Pollut. Bull.* 128, 353e360.
- 30
31 Simon-Sánchez, L., Grelaud, M., Franci, M., Ziveri, P., 2022. Are research methods shaping our understanding
32 of microplastic pollution? A literature review on the seawater and sediment bodies of the Mediterranean
33 Sea, *Environ. Pollut.* 292, 118275.
- 34
35 Solo-Gabriele, H.M., Harwood, V.J., Kay, D., Fujioka, R.S., Sadowsky, M.J., Whitman, R.L., et al., 2016. Beach
36 sand and the potential for infectious disease transmission: observations and recommendations. *J. Mar. Biol.*
37 *Assoc. U.K.* 96, 1, 101–120.
- 38
39 Suaria, G., Aliani, S., 2014. Floating debris in the Mediterranean Sea. *Mar. Pollut. Bull.* 86, 494e504.
- 40
41 Suaria, G., Avio, C.G., Mineo, A., Lattin, G.L., Magaldi, M.G., Belmonte, G., Moore, C.J., Regoli, F., Aliani, S.,
42 2016. The mediterranean plastic soup: synthetic polymers in mediterranean surface waters. *Sci. Rep.* 6, 1e10.
- 43
44 Taïbi, N.-E., El Amine Bentaallah, M., Alomar, C., Compa, M., Deudero, S., 2021. Micro- and macro-plastics in
45 beach sediment of the Algerian western coast: First data on distribution, characterization, and source. *Mar.*
46 *Pollut. Bull.* 165, 112168.
- 47
48 Thompson, R.C., Moore, C., vom Saal, F.S., Swan, S.H., 2009. Plastics, the environment and human health:
49 current consensus and future trends. *Philos. Trans. R. Soc. B* 364, 2153–2166.
- 50
51 Tudor, D.T., Williams, A.T., Randerson, P., Ergin, A., Earll, R.E., 2002. The use of multivariate statistical
52 techniques to establish beach debris pollution sources. *J. Coast. Res.* 36, 716–725.
- 53
54 Tudor, D., Williams, A., 2004. Development of a 'Matrix Scoring Technique' to determine litter sources at a
55 Bristol Channel beach. *J. Coast. Conserv.* 9, 119-127.
- 56
57
58
59
60
61
62
63
64
65

- 1 UNEP/MAP MEDPOL, 2011. Assessment of the status of marine Litter in the Mediterranean Sea.
2 UNEP(DEPI)/MED WG.357/Inf.4.
- 3 UNEP/MAP, 2012. State of the Mediterranean Marine and Coastal Environment. UNEP/MAP, Athens,
4 Barcelona Convention.
- 5
6 UNEP/MAP, 2015. Marine Litter Assessment in the Mediterranean. ISBN: 978-92-807-3564-2.
- 7
8 UNEP/MAP MEDPOL, 2015. Updated Report on Marine Litter Assessment in the Mediterranean.
9 UNEP(DEPI)/MED WG.421/Inf.18.
- 10
11 UNEP/MAP, 2016. Integrated Monitoring and Assessment Guidance. UNEP(DEPI)/MED IG.22/Inf.7.
- 12
13 Van Acoleyen, M., Laureysens, I., Stijn, L., Raport, L., Van Sluis, C., Kater, B., et al., 2013. ARCADIS Final report
14 Marine Litter study to support the establishment of an initial quantitative headline reduction target
15 SFRA0025 European Commission DG Environment Project number BE0113.000668.
- 16
17
18 Veiga, J. M., Fleet, D., Kinsey, S., Nilsson, P., Vlachogianni, T., Werner, S., et al., 2016. Identifying sources of
19 marine litter. MSFD GES TG Marine Litter Thematic Report. JRC Technical Report.
20 <https://doi.org/10.2788/018068>.
- 21
22
23 Velander, K.A., Mocogni, M., 1998. Maritime litter and sewage contamination at Cramond Beach Edinburgh
24 - a comparative study. *Mar. Pollut. Bull.* 36 (5), 385–389.
- 25
26 Vlachogianni, T., Fortibuoni, T., Ronchi, F., Zeri, Ch., Mazziotti, C., Tutman, P., Varezic, D.B., Palatinus, A.,
27 Trdan, S., Peterlin, M., Mandic, M., Markovic, O., Prvan, M., Kaberi, H., Prevenios, M., Kolutari, J., Kroqi, G.,
28 Fusco, M., Kalampokis, E., Scoullou, M., 2018. Marine litter on the beaches of the adriatic and ionian seas: an
29 assessment of their abundance, composition and sources. *Mar. Pollut. Bull.* 131 (A), 745–756.
- 30
31
32 Vlachogianni, T., Skocir, M., Constantin, P., Labbe, C., Orthodoxou, D., Pematzoglou, I., Scannella, D., Spika,
33 M., Zissimopoulos, V., Scoullou, M., 2020. Plastic pollution on the Mediterranean coastline: generating fit-
34 for-purpose data to support decisionmaking via a participatory-science initiative. *Sci. Total Environ.* 711,
35 135058.
- 36
37
38 Wenneker, B., Oosterbaan, L. 2010. Guideline for Monitoring Marine Litter on the Beaches in the OSPAR
39 Maritime Area. OSPAR Commission. ISBN: 90-3631-973-9.
- 40
41
42 Werner, S., Budziak, A., van Franeker, J., Galgani, F., Hanke, G., Maes, T., Matiddi, M., Nilsson, P., Oosterbaan,
43 L., Priestland, E., Thompson, R., Veiga, J., Vlachogianni, T., 2016. Harm caused by marine litter. MSFD GES TG
44 Marine Litter – Thematic Report. JRC Technical report. EUR 28317 EN.
- 45
46
47 Wilcox, C., Mallos, N.J., Leonard, G.H., Rodriguez, A., Hardesty, B.D., 2016. Using expert elicitation to estimate
48 the impacts of plastic pollution on marine wildlife. *Mar. Policy* 65, 107–114.
- 49
50
51 Williams, A.T., Micallef, A., 2009. Beach Management. Principles and Practice. Earthscan, London, ISBN 978-
52 1-84407-435-8, 480 pp.
- 53
54
55 Williams, A.T., Rangel-Buitrago, N., 2019. Marine litter: solutions for a major environmental problem. *J. Coast.*
56 *Res.* 35 (3), 648–663
- 57
58
59 World Tourism Organization, 2018. UNWTO Tourism Highlights. 2018 edn, UNWTO, Madrid.
- 60
61
62
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Zielinski, S., Botero, C.M., Yanes, A., 2019. To clean or not to clean? A critical review of beach cleaning methods and impacts. *Mar. Pollut. Bull.* 139, 390–401.

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Table S1. Summary of the publications results obtained through the different search strings applied. The number of available publications and their time frame are listed. Although it does not represent a selective criterion in the presented analyses, the number of open access publications is also reported. Since spelling and plurals are often used in title, abstract and keywords, we included the use of the asterisk wildcard (i.e., *) to ensure the inclusion of derived words (e.g., beached from beach*, coastal from coast*).

| Search string | Number of publications | Time frame | Open Access |
|---|------------------------|------------|-------------|
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (mediterranean)) | 206 | 1978-2021 | 51 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (tyrrhenian)) | 14 | 1991-2020 | 2 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (aegean)) | 19 | 2000-2021 | 3 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (adriatic)) | 29 | 2000-2021 | 7 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (algerian)) | 2 | 2018-2021 | 1 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (balearic)) | 8 | 2001-2021 | 4 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (ligur*)) | 5 | 2008-2021 | 0 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (israel*)) | 17 | 1978-2021 | 1 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (alboran)) | 1 | 2021 | 1 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (ionian)) | 10 | 2006-2021 | 0 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (levantine)) | 3 | 2018-2019 | 0 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (tunisi*)) | 10 | 1998-2021 | 82 |
| TITLE-ABS-KEY (beach* AND (marine OR coast*) AND (litter OR debris OR waste OR *plastic) AND (mediterranean OR tyrrhenian OR balearic OR aegean OR adriatic OR ionian OR levantine OR alboran OR israel* OR ligur* OR tunisi* OR egypt* OR algerian)) | 255 | 1978-2021 | 58 |

Table S2. Occurrence of documents indexed in Scopus excluded after the title and abstract screening by category (in percentage).

| Category | Percentage of total excluded documents |
|---|--|
| Environmental compartments (water surface, seafloor, sediment, biota) | 33.7 % |
| Geology and paleogeology | 28.8 % |
| Technology and biotechnology | 13.5 % |
| Health and water quality | 9.6 % |
| Coastal and landscape management | 8.6 % |
| Different study area | 5.8 % |

Table S3. Surveyed sites information from scientific collections identified by ID numbers, as in Table 1. In parenthesis, the exact number of sites falling into a given category, if explicitly stated in the analysed documents.

| ID | Beach typology (sites) | coastal type (sites) | Protected area |
|----|--|---|----------------|
| 1 | | sandy, rocky | |
| 2 | | sandy, rocky | |
| 3 | | sandy, cobbles, rocky | |
| 4 | | | |
| 5 | | sandy (5), gravel (1) | |
| 6 | | | |
| 7 | | | |
| 8 | | | |
| 9 | | sandy | |
| 10 | touristic / non-touristic | | |
| 11 | urban, semi-urban, semi-rural | sandy | |
| 12 | | sandy, rocky | |
| 13 | exposed (3), sheltered (4) | sandy | |
| 14 | | sandy | |
| 15 | | sandy (12), small gravel (1) | |
| 16 | | sandy | yes |
| 17 | urban (1), remote (2), semi-rural (1) | sandy (3), pebbles and cobbles (1) | |
| 18 | natural | sandy | |
| 19 | natural, urbanized, urban | sandy | yes |
| 20 | urban, semi-urban, semi-rural, remote | | |
| 21 | wetland | | |
| 22 | urban, village, rural, remote | cliffed, sandy | |
| 23 | | sandy | |
| 24 | | sandy | |
| 25 | urban (6), village (2), resort (2), rural (4) | cliffed, sandy | |
| 26 | | sandy, gravel | |
| 27 | urban | sandy | |
| 28 | | | |
| 29 | remote | | |
| 30 | natural, semi-urban | sandy, rocky | |
| 31 | very touristic, used by locals, remote | | |
| 32 | urban | sandy | |
| 33 | | sandy | |
| 34 | agricultural (5), industrial (3), urban (3), rural (2) | sandy (11), gravel (2) | |
| 35 | | sandy, rocky, pebbles | yes |
| 36 | semi-urban (2), urban (2), semi-rural (1) | | |
| 37 | remote and rural (19), village (17), urban (20) | sandy, gravel, pebbles, rocky, low cliff, artificial | |
| 38 | remote (9), rural (10), village (17), urban (20) | sandy (31), gravel (14), boulders (14), rocky (8), banquettes (6), artificial (1) | |
| 39 | semi-urban, semi-rural, remote/natural | sandy, gravel, pebbles | |
| 40 | urban, semi-urban, semi-rural, remote/natural | | |
| 41 | remote/natural | sandy | |

| | | | |
|----|----------------------------------|--|-----|
| 42 | wetland | sandy | yes |
| 43 | urban | stones, sandy | |
| 44 | semi-rural | rocky | |
| 45 | | sandy | yes |
| 46 | urban (7), rural (2), remote (3) | sandy (2), gravel (2), sandy and gravel (7), pebbles (1) | |
| 47 | river estuary | sandy | |
| 48 | | | |
| 49 | urban (3), village (2) | sandy | |
| 50 | Wetland | sandy | yes |
| 51 | Urban | sandy (8), boulders and cliffs (2) | |
| 52 | Lagoon | sandy | yes |
| 53 | Lagoon | sandy | |
| 54 | rural (2), remote (3) | cobbles | |
| 55 | Wetland | sandy | yes |
| 56 | | sandy | yes |
| 57 | | pebbles | |
| 58 | Wetland | sandy | yes |

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: