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Litter Windrows in the South-East Coast of the Bay of Biscay: An Ocean Process Enabling Effective Active Fishing for Litter

*Irene Ruiz[1]**, Oihane C. Basurko[1], Anna Rubio[1], Matthias Delpey[2], Igor Granado[1], Amandine Declerck[2], Julien Mader[1] and Andrés Cózar[3]*

[1] AZTI, Marine Research, Basque Research and Technology Alliance (BRTA), Pasaia, Spain, [2] Rivages Pro Tech, SUEZ Eau France, Bidart, France, [3] Departamento de Biología, Campus de Excelencia Internacional del Mar, Instituto Universitario de Investigaciones Marinas, Universidad de Cádiz, Puerto Real, Spain

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***Correspondence:**
Irene Ruiz
iruiz@azti.es

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Large scale convergence regions of floating marine litter are commonly observed in semi-enclosed seas as the Bay of Biscay. However, clean-up activities on such accumulation regions are limited by the spread of the large-size floating litter on the sea surface. Data gathered by a small-scale fishing vessel devoted to active fishing for floating litter activities during the spring and summer of 2018 reveals that the linear streaks of high concentration of floating litter (so-called litter "windrows") are common accumulation structures in the south-east coast of the Bay of Biscay. The random search of litter windrows for their collection through surface tows of macro-nets was proved to be an effective action for floating litter mitigation. A total of 196 tows collected 16.2 tons of floating marine litter in 68 working days. Most of the litter windrows were around 1 km length and, on average, accumulated 77.75 kg of floating marine litter. Fishing, shipping and aquaculture sectors were the source of 35% of the 4,130 litter items analyzed (55% in weight of the sourced items), and plastic was the most common type of material (96% in terms of items). A better understanding of the phenomenon of the litter windrows, capable to guide clean-up efforts in space and time, would provide a considerable improvement in the efficiency of mitigation actions to reduce the marine litter pollution. The observations of litter windrows in the coastal area of the south-east of the Bay of Biscay demonstrate the key role of submesoscale processes in the distribution of FML. The present work provides a thorough description of floating litter windrows in nature, which it was non-existent to date. The results are the kind of proof necessary to boost the research addressed on the submesoscale aggregations of FML. Coupling litter windrows observations with remote-sensing technology and high-resolution modeling techniques offer great opportunities for the mitigation actions against marine litter.

Keywords: floating marine litter, litter windrows, Bay of Biscay, active fishing for litter, coastal integrated management, LIFE LEMA

INTRODUCTION

About half of the floating marine litter (FML) in the world is thought to be confined in great accumulation zones or hot spots (UNEP, 2016). Much attention has been paid to understand the global convergence zones associated to the subtropical gyres (Law et al., 2010; Eriksen et al., 2013; Cózar et al., 2014; Lebreton et al., 2018). Nevertheless, global models also consistently predict litter accumulation zones in semi-enclosed seas as the Bay of Biscay, where the concentration of FML is higher in comparison to other European regions (Lebreton et al., 2012; van Sebille et al., 2012). Besides, regional models point to the importance of FML accumulation zones in the coastal waters of the south east Bay of Biscay (SE Bay of Biscay) caused by the combination of relatively long residence times ant the litter influx from both local and remote areas (Pereiro et al., 2018). Moreover, the predicted FML accumulations in this area seem to be significantly modulated at seasonal scale. During spring and summer, the more variable and weaker currents result in high particle retention, while the northward evacuation of particles along the French coast are favored during autumn and winter by the typical surface current regime (Declerck et al., 2019).

At smaller spatio-temporal scales (<10 km or <1 month), the accumulation of FML near the coastal areas show high variability in response to the combined effect of different small-scale processes such as surface wave interactions with current and mixing, Langmuir circulation and (sub) mesoscale eddies. These events lead to create a heterogeneous and patchy litter field on the surface of the ocean (UNEP, 2016; van Sebille et al., 2020). However, most of the existing operational coastal models are configured with spatio-temporal scales not suited to capture this small-scale variability, which is key to monitor and predict the FML distribution in coastal areas, as it happens in the case of the SE Bay of Biscay. Likewise, field investigations conducted so far to assess its abundance and the distribution have been limited to visual ship transects surveys with reduced spatial resolution (Boyra et al., 2013).

The magnitude of the impacts derived from FML in the European waters has been highlighted by the European Marine Strategy Framework Directive (MSFD) (EC, 2008) which invited member states to promote a cross-border and transnational cooperation on this issue to adopt strategies to combat marine litter. However, international efforts to collect FML in the globally predicted convergence zones have been limited. One of the difficulties in setting targets and mitigation plans for FML is the lack of field data and methodologies for ensuring their effectiveness.

In the SE Bay of Biscay, at the Atlantic border between France and Spain, local authorities have funded active fishing for FML activities [“active retrieval of marine litter by vessels that have been paid to perform this activity” (UNEP(DEPI)/MED, 2016)] in the French coastal area since 2003. This action, closely aligned with the European policy requirements, responds to the growing amount of litter affecting the local beaches. FML accumulated in the convergence areas close to the coast is likely to end washed up on beaches, with the consequent environmental and socio-economic impact for a very touristic region like the SE Bay of Biscay.

The above-mentioned active collection of FML is carried out by an artisanal fishing vessel, *Itsas Belarra*, based in Saint Jean de Luz port (Pyrénées-Atlantiques, France) and chartered by the Syndicat Mixte Kosta Garbia, an association gathering local public authorities committed to the fight against FML. The Itsas Belarra combines the collection of FML (from May until September) with the fishing of seaweed for commercial purposes, the latter taking place during fall and winter. After more than a decade of operation, the collection of FML has gained in efficiency since the efforts are concentrated along linear streaks with high concentration of litter. called litter “windrows” (Frontiers in Marine Science, 2020). Although there are some references to these small-scale convergence features in the literature, little is known regarding the way litter is accumulated in such areas, their residence times, and the physical drivers forming such structures. Since a better understanding of this processes could have a direct impact in the optimization of FML collection, the activity of the Itsas Belarra was protocolized and monitored during several months in the framework of the EU co-funded LIFE LEMA project. Moreover, active fishing for litter can provide initial estimates of FML distribution patterns, type and sources. This latter aspect is also key since sources of marine litter are diverse and ocean dynamics turn it into a transboundary issue requiring collective action (OSPAR, 2014).

Within this context, with the aim of improving the integrated monitoring of the coastal waters of the SE Bay of Biscay in the framework of JERICO-S3 project, this contribution aims at assessing the litter windrows' features in the area through a scientifically assessed active fishing for litter activity. The data obtained provides, for the first time, estimates of loading, composition, frequency and size of the litter windrows as well as experience for its collection. The analysis is aimed to improve forthcoming fishing for litter collection activities across the region with possible application to other coastal areas under similar forcings and pressures.

MATERIALS AND METHODS

Sampling of Litter Windrows

The data used in this contribution relates to the Itsas Belarra's active fishing for litter activity, mainly oriented to FML collection in litter windrows within the south-west French coastal area during spring and summer 2018 (**Figure 1**). Litter windrows were detected by the crew by visual observations and net tows were carried out along the litter windrow following the streak of higher FML concentrations (**Figure 2**). The fishing gear employed for the collection consisted of an artisanal net adapted for FML collection, featuring a rectangular metallic frame and a nylon net with a 20 mm mesh size. Thus, clean-ups were focused on the so-called macro litter (>2 cm), which is the most easily retrievable form of litter pollution. The net covered the first 30–50 cm from the sea surface, depending on the sea conditions. The collection was carried out at a speed $\leq$ 3 knots. The duration per tow varied between 3 and 60 min depending on the amount of FML collected. The net was monitored by the crew during each trawl to avoid an overload of the net and

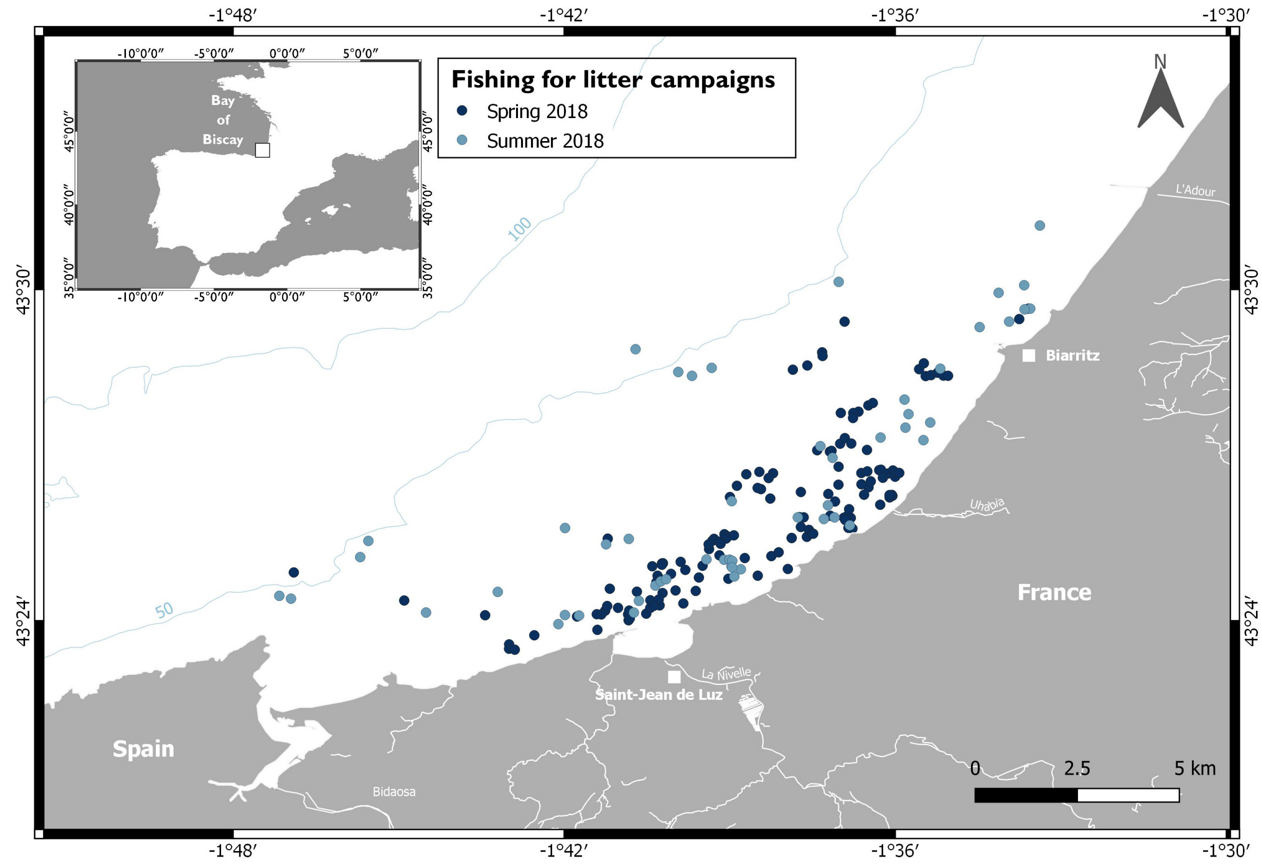

FIGURE 1 | Location of the study area. Circles show the initial positions of the tows.

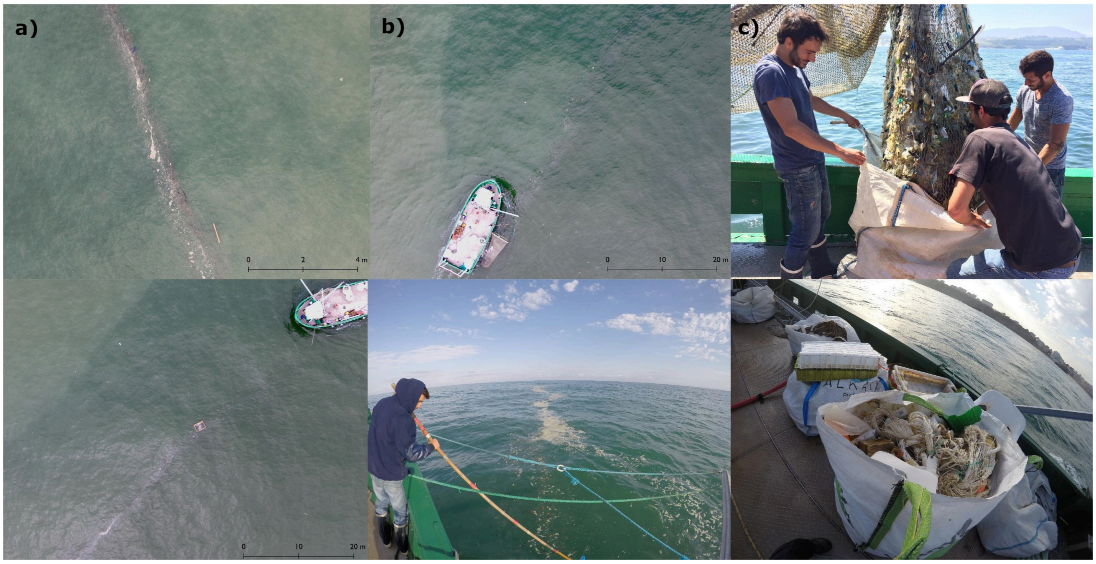

FIGURE 2 | FML collection throughout the litter windrow **(a)** Airborne pictures of litter windrow collected by a drone survey, **(b)** Vessel operating during collection, **(c)** Unloading of FML and storage on board. Written informed consent was obtained from the Itsas Belarra crew for the publication of any potentially identifiable images or data included in this article.

to simplify its post-handling. Litter windrows also accumulated natural wooden fragments and seaweed. However, large wooden fragments were avoided by using brailers in order to prevent damaging the net. Although some of these large natural items were collected by hand and stored onboard for navigation safety purposes, they were not systematically sampled. A dedicated energy monitoring device, named SIMUL (developed by AZTI, Gabiña and Basurko, 2018) was installed onboard to provide position coordinates, time and speed of the vessel, with a 0.1 Hz frequency. This information was completed by the location and time data from the Marine Navigation Software MaxSea, available onboard. Moreover, information regarding initial position and initial time of each tow was manually recorded by the crew in a spreadsheet. Once the tow finished, FML was stored in a coded big bag, which was subsequently weighted onboard with a load cell. Finally, the different information recorded about each tow was reported daily by the crew through a dedicated web interface implemented as part of the LIFE LEMA project.

Processing of Tow Data

A detailed analysis on the track record was carried out based on the speed range of the vessels. It was considered that at vessel speeds $\leq$ 3 knots the vessel was involved in towing the net; in contrast, at speeds $>$ 3 knots the vessel was sailing to new locations, searching for litter, or going/coming back from the port. Thanks to the analysis: (1) the initial location of the tow was verified, and (2) the final position identified. The cases in which no data from SIMUL device was available, speed was calculated directly by the division of distance and time values covered between consecutive positions of the vessel provided by the MaxSea software. During the weighting of the catch, the litter was wet. A 2.47 wet/dry FML litter ratio was applied to Itsas Belarra weight values, based on lab tests with the collected litter.

Distribution Analysis

A total of 68 fishing days and 166 tows seasonally distributed were selected and analyzed in detail (**Supplementary Figures 1–7**). The results are based on the assumption that every tow corresponds to a litter windrow; in contrast, for the cases that the vessel follow a very chaotic path, it was assumed that the litter accumulated in patches, so 30 tows were discarded. The study area was discretized into a 0.5 km $\times$ 0.5 km grid cell. The weight of the FML retrieved in every tow was divided equally into the number of positions recorded along the tow, and the resulting weight values were assigned to the corresponding position and plotted in the map. The accumulated distribution of weight values per cell for the whole campaign was calculated by adding every weight value inside the same cell. Weight data were displayed separately by season to assess its influence for spring 2018 and summer 2018. Histograms of the weight and length of the litter windrows were plotted. A first exploration of the environmental conditions leading to windrows formation was performed through the analysis of prevailing wind direction, wind speed, and number of litter windrow observed for spring and summer 2018. To that end, a weighted average of wind speed and the mode of the prevailing wind directions were calculated for the 48 h previous to the observation dates, based on the hourly wind data provided by Bilbao-Vizcaya buoy (Measuring Networks and Forecasting Systems of Puertos del Estado)[1].

Characterization by Composition and Source

A total of 11 samples were randomly collected from the big bags for their further analysis in lab, with the aim of characterizing the marine litter collected in the windrows and defining its potential sources. Almost 240 kg of the litter items collected were sorted out according to the Master list included in the "Guidance on Monitoring of Marine Litter in European Seas" (Galgani et al., 2013). As a result, the items $>$ 2.5 cm were sorted in 7 main categories based on their material (artificial polymer materials, rubber, cloth/textile, wood/processed wood, paper/cardboard, metal, and glass/ceramic) and 68 sub-categories based on their typology. The list was regularly updated during the analysis process to incorporate new item sub-categories that were omitted in the Guidance but were present in the waters of the SE Bay of Biscay (**Supplementary Table 1**). Items were also weighed by group of sub-categories using an electronic balance with a precision of $\pm$0.01 g. The ten most common items in number and in weight were also identified. Non-anthropogenic items collected by the nets were omitted in this study. The items $<$ 2.5 cm were classified as microplastics.

In line with the most common categorization of marine litter origins, items were allocated to *land – based sources* and *sea – based sources* categories. One more specific category, *non-sourced*, was added to classify the litter items that could not be directly connected to either of the two groups. Based on the OSPAR indicator-items methodology (Veiga et al., 2016), a subsequently division was defined by distinguishing fishing and shipping activities for sea–based sources and Tourism and Recreational activities and Sanitary and sewage-related waste for land–based sources. Sources, expressed as a percentage contribution of each category, were also analyzed by type of material to explore their relationship with the litter composition. In total, 4,130 litter items were classified and weighted.

RESULTS

Litter Windrows Features

During spring and summer 2018, the Itsas Belarra collected 14 tons of FML by towing the net in 166 litter windrows. The number of litter windrows was, by far, higher during spring (74.10%, 123 litter windrows) than summer 2018 (25.90%, 43 litter windrows). This difference between seasons (**Figure 3**) was also observed regarding the weight of FML collected per windrow. As an average, the litter windrows included 91.74 $\pm$ 53.137 kg of FML during spring and 62.96 $\pm$ 39.63 kg during summer (min-max: 10–195 kg), which revealed less loaded windrows during the summer. In contrast, the mean length of the litter windrows was quite similar in both seasons (1.01 – 1.47 km); nonetheless, longer litter windrows ($>$3 km) were more frequent in summer (11%) than in spring (0.7%).

[1] http://www.puertos.es/

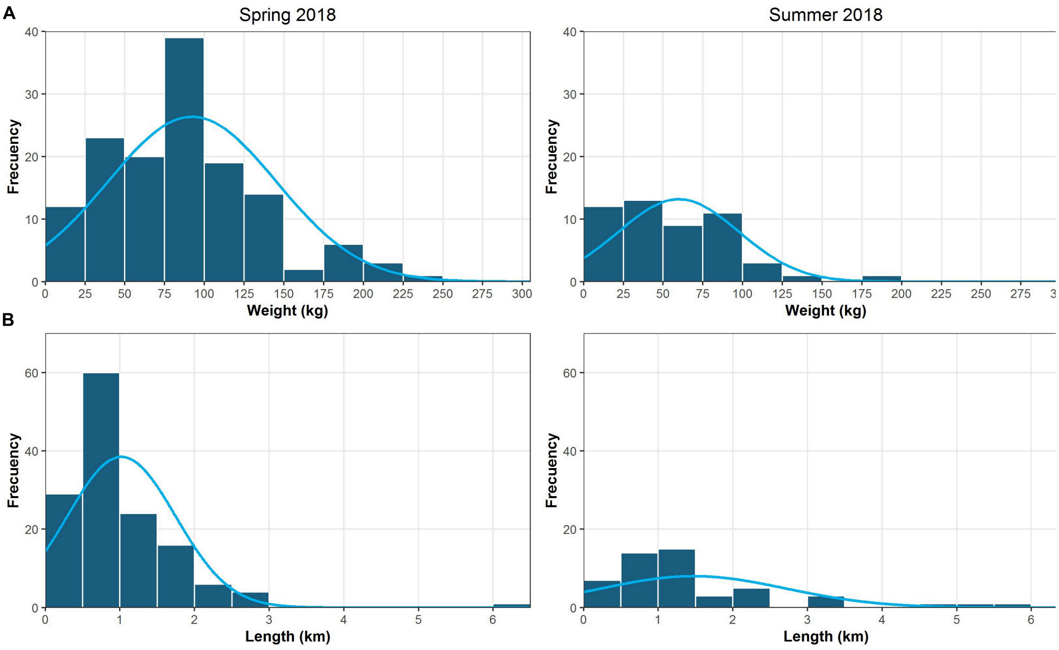

FIGURE 3 | Distribution of FML wet weight **(A)** and length **(B)** of litter windrows during spring (left plot) and summer 2018 (right plot).

Spatial Distribution

Significant accumulation areas were located within the first nautical mile from the coastline, mainly during spring 2018 (**Figure 4** and **Supplementary Figures 8**, **9**). The highest loads per windrow (>300 kg) were also collected during this season. During summer 2018, a considerably lower amount of FML was observed comparing to spring. During this period, litter was unevenly spatially distributed. However, similar abundance values among the cells (1–50 kg) indicates the lack of heavy accumulation areas. Few isolated cells included presence of litter in both seasons, most of them coinciding also to low weight values (1–50 kg). The analyses on wind conditions showed that the litter windrows were mainly linked to low intensity westerly and easterly winds (0–4 m/s) in spring and to southerly winds in summer(**Figure 5**).

Composition and Sources

Plastic, found in the 100% of the samples, was the dominating sub-category by number of items and weighing. In terms of number of items, *Plastic pieces*, *strings and cords* and *Other plastic/polystyrene items* were the most common sub-categories found (regardless their origin), comprising over 71.43%. In contrast, in terms of weight, *Nets and pieces of net*, *Other plastic/polystyrene and Floats for fishing nets* were the most frequent, representing 48% of the total litter (**Figure 6**). Items belonging to the rest of the sub-categories were collected occasionally, accounting only the 3.38% in number. Nevertheless, *Glass/Ceramics* was the second most abundant sub-category according to weight values, while the less common sub-categories represented the 2.21% of the litter collected. The rest of the top-ranking varied widely according number and weighing values though *tangled nets/cords* and single use items as *Food containers* or *Drink bottles* were also frequently recorded.

Regarding the origin of the collected marine litter, it must be noted that it was not possible to assign a large amount of items to neither sea nor land-based origin because they were unidentifiable fragments or their origin could be both. This *Non-sourced items* represented over the 43.99% of items collected. The importance of this source was highlighted by the fact that *plastic pieces* (2.5 cm > < 50 cm) represented the over the 40% of total items encountered.

Concerning the material which source could be determined (**Figure 7**), *Sea-based sources* contributed in a 35% and included primarily items from fishing activities (including aquaculture); *string and cords* summed the third of the litter collected. *Land-based sources* related to tourism and recreational activities were not very common in the litter collected and only reached values over 3%. Very few sanitary items were found in the marine litter, amounting less than 0.8%. Packaging items (food and drink) consisting of *drink bottles*, *food containers,* and what remains of *rip-off plastic bags* accounted for 6.68% of *Non-sourced* origin items. Single-use plastics, entering the ocean from multiple sources and pathways, account for 18.5%.

DISCUSSION

Litter Windrows in the Coastal Waters of SE Bay of Biscay

Marine litter dispersion and washing-up on shore are strongly influenced by ocean currents, tidal cycles, regional-scale topography (including sea-bed topography) and

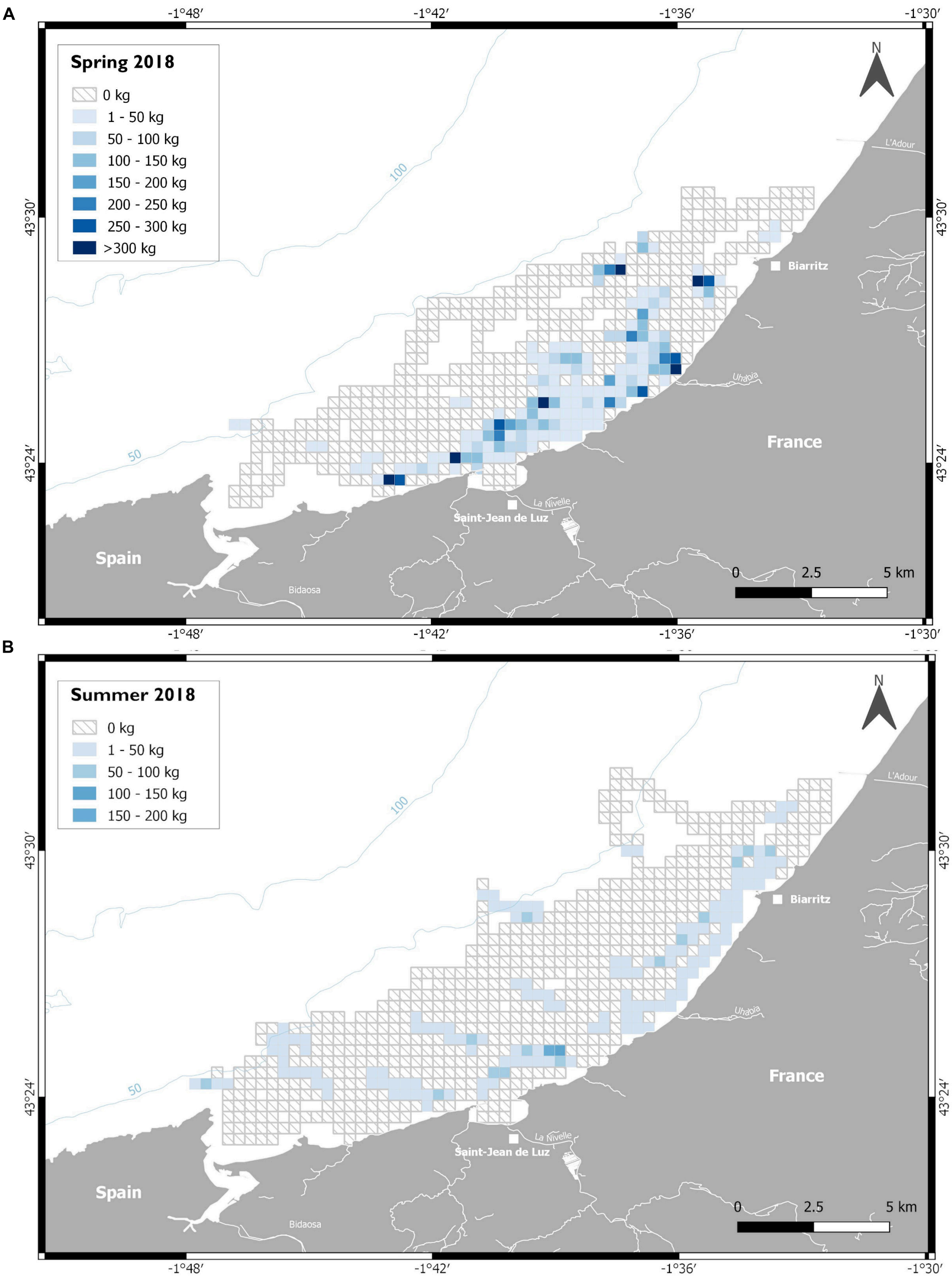

FIGURE 4 | Abundance of FML in the litter windrows calculated per cell of 0.5 km × 0.5 km for spring **(A)** and summer 2018 **(B)**.

wind (Jeftic et al., 2009). These, hydrodynamic factors and geomorphological characteristics of the coastline, coupled by riverine inputs and the presence of anthropogenic activities are the main factors modulating the presence of marine litter in the coastal area (Wei et al., 2012; Ramirez-Llodra et al., 2013). However, there are large variations on their concentration at small scales due to the complexity of local coastal dynamics and interactions with the wind (Law et al., 2014). The results

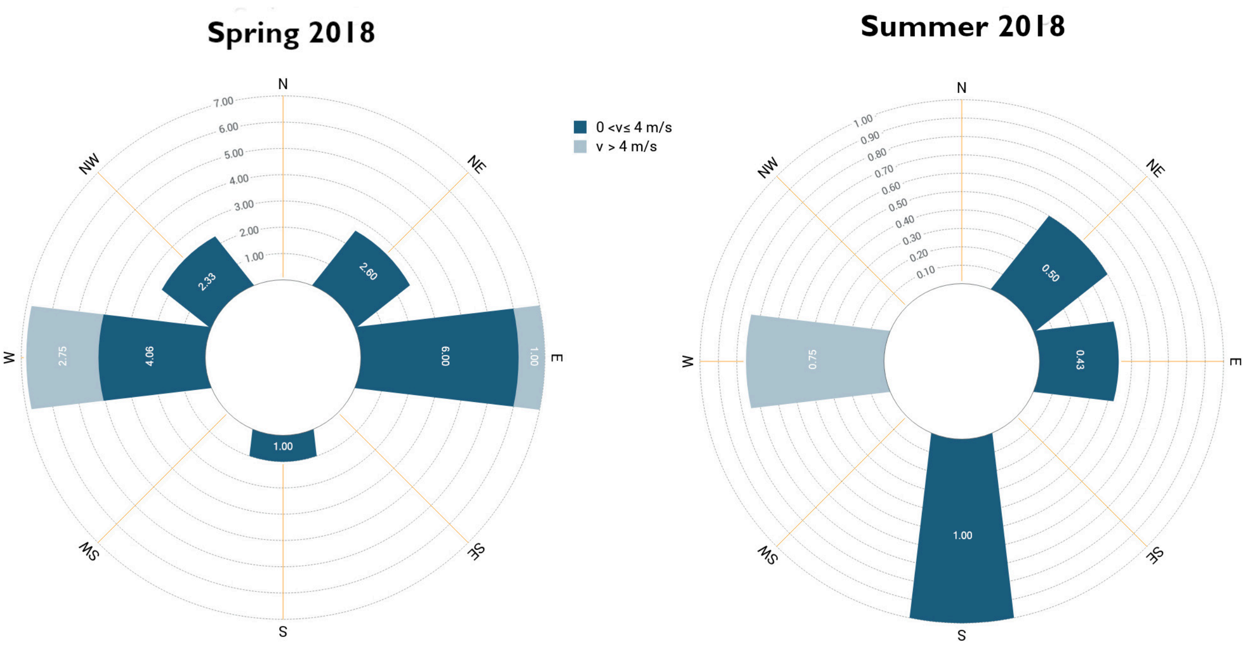

FIGURE 5 | Wind direction and intensity during the litter windrow events in spring and summer 2018. Number of litter windrows occurrence during spring and summer 2018 regarding to wind direction and intensity.

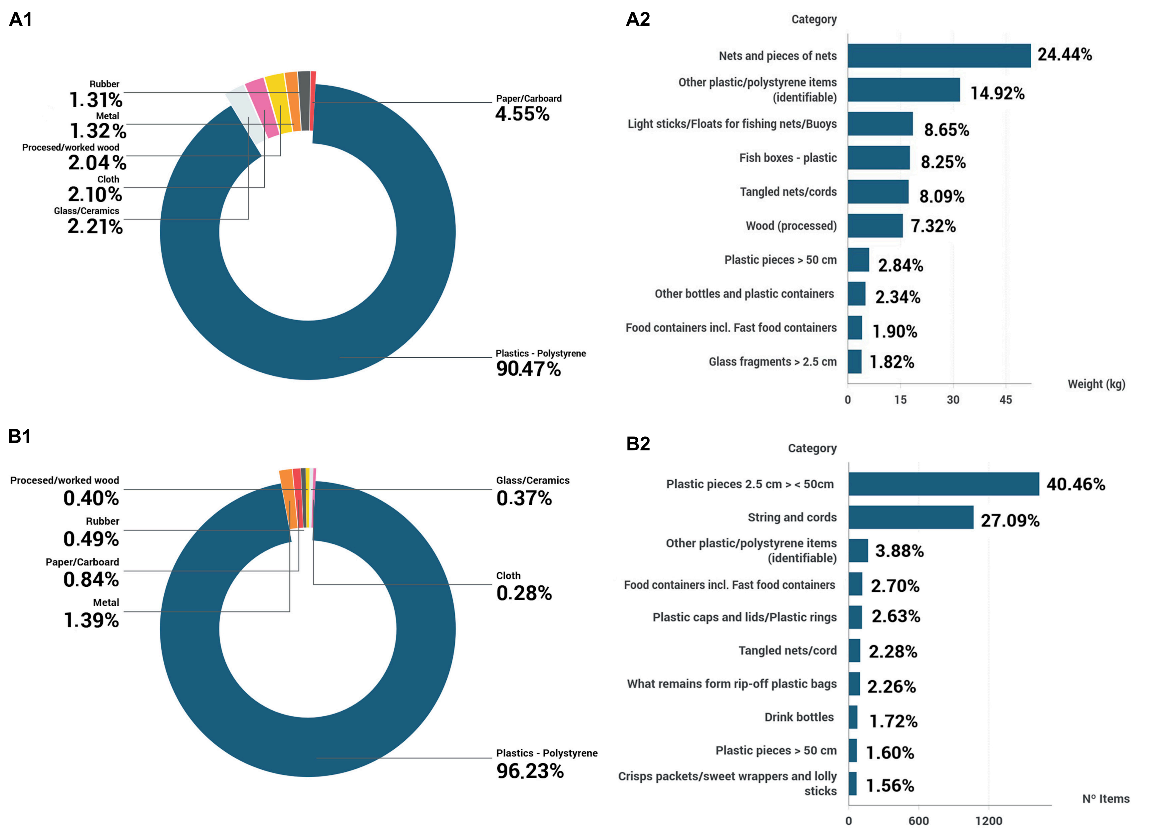

FIGURE 6 | Percentage of number **(A1)** and weight of items **(B1)** collected by type of material, and Top 10 of 554 items collected by weight **(A2)** and by number **(B2)**.

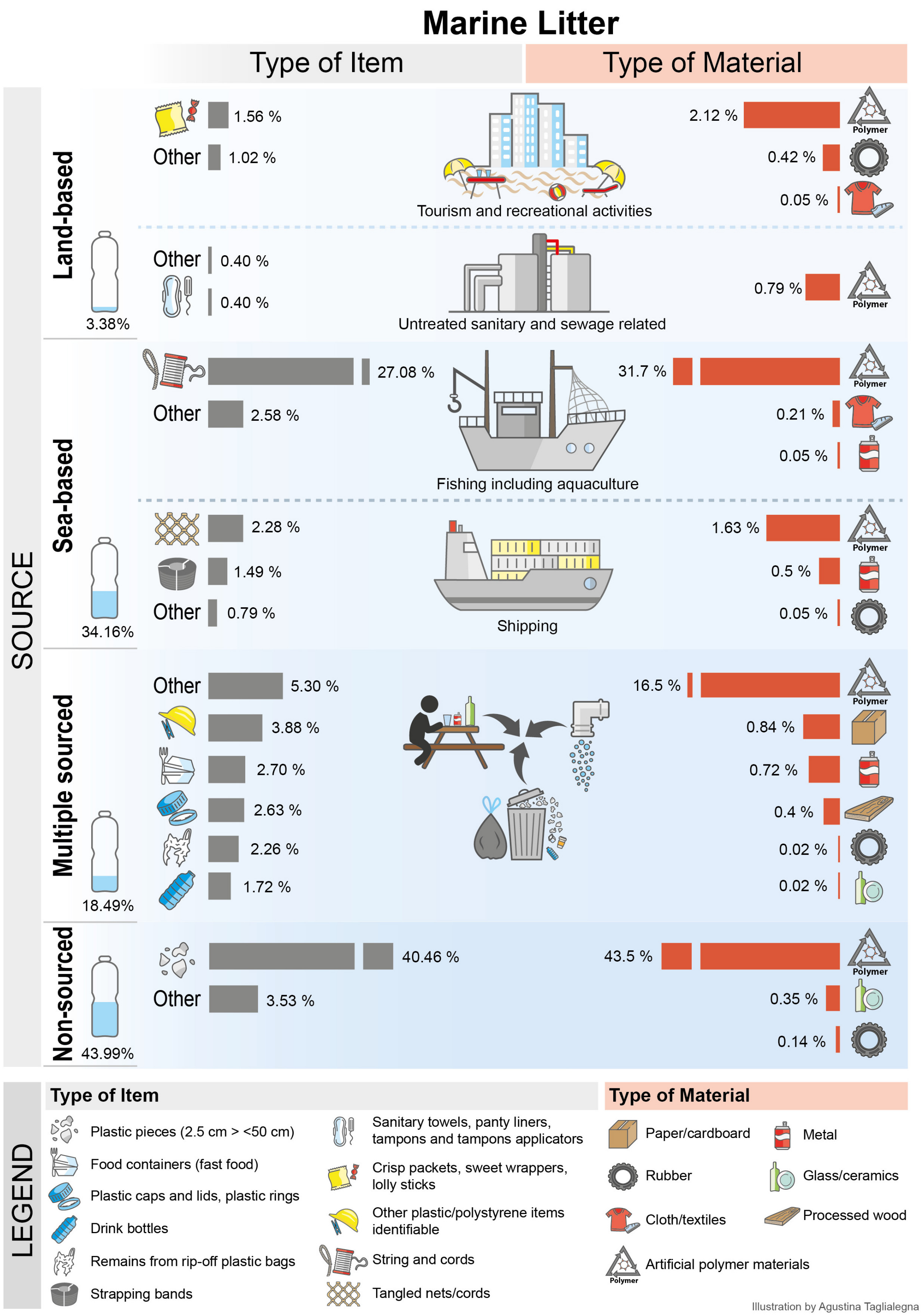

FIGURE 7 | Percentage of litter items collected per source and related to type of material.

obtained by our study in the SE Bay of Biscay are a showcase on how small-scale processes can play an important role in shaping the distribution of FML. For the first time, a small-scale characterization of the FML hotspots is provided, demonstrating that rectilinear litter windrows are frequent and significant accumulation structures in the coastal waters of the SE Bay of Biscay. Higher loads of litter were found at short distances (1 nm) from nearby the coast rather than at farther locations. Variability in time, with higher litter amounts being collected in spring, matched with findings from numerical modeling in this coastal region (Declerck et al., 2019) which pointed out higher residence times in this period. Significant differences in the number, length and load of FML were found between spring (shorter lengths, higher loads) and summer (longer lengths, lower loads) windrows. Nevertheless, it is important to note that the net capacity can limit the windrows length. In higher loads, net can get full and consecutive tows can be observed. This means that the cleanup of all litter into a single windrow occasionally required more than one net tow.

The research about processes leading to the formation, presence and persistence of litter windrows in the study area is out of the scope of the present paper but the first exploration of the wind conditions suggested there was no evidence found on a statistically significant linear relation between wind intensity and litter windrows occurrence.

In a recent observational study (Meyerjürgens et al., 2019) show that FML transport in coastal areas is strongly influenced by local small-scale processes like tidal jet currents, interactions with a complex shoreline and fronts generated by riverine freshwater plumes. In the study area, litter windrows generation could also relate to the Adour river plume. This river shows a mean annual discharge about 300 m^3 s^{-1} (Morichon et al., 2008), with peak flows exceeding 1000 m^3 s^{-1} (Laiz et al., 2014) and a summer runoff under 500 m^3 s^{-1} (Declerck et al., 2019). The density fronts associated to the Adour freshwater discharge leads to the formation of small-scale surface convergence zones. Further analysis combining *in situ* observations with surface current observations, surface drifters and numerical models are needed to better understand its origin and functioning. How the windrows form and evolve in coastal areas appears to be key to improve the efficiency of the FML collection, particularly in nearshore waters, where accessibility and operating costs are smaller than those in offshore waters. Coupling litter windrows observations with remote-sensing and high-resolution modeling provide significant opportunities to advance up the identification of periods and zones of FML accumulation. However, from our experience, it should be noticed that the use of such images to support FML removal operations raises significant challenges. Indeed, high-quality satellite images may be rarely available on a specific targeted date such as previously to a field campaign. Daily images could be available but are rather costly. Free satellite images (e.g., Sentinel-2) are available but on weekly or bi-weekly basis, which is too long compared to the coastal dynamics. Finally, even when available, cloudiness is a hindrance in the high rainfall study region, which limits the possible exploitation of optical images Sources of litter in the coastal waters of SE Bay of Biscay.

SOURCES OF LITTER IN THE COASTAL WATERS OF SE BAY OF BISCAY

Marine litter windrows in the study area were mainly composed by plastic (96% in terms of items; 76.40% in weight), in agreement with worldwide ranges reported (UNEP and Grid-Arendal, 2016). The Bay of Biscay is an internationally important region for fishing, aquaculture and shipping (Borja et al., 2019) and our results point at these sea-based activities as the main source of FML (35% of the litter by number and 55% by weight). In the North-East Atlantic and other European Seas, the contribution of land-based sources is prevalent (Reker et al., 2015). The abundance of litter related to fishing activities (mainly floats/buoys) increase in the open ocean, and becomes predominant in weight (Eriksen et al., 2014).

EU is playing a leading role in tackling abandoned, lost or otherwise discarded fishing gears, which account for 27% of total litter stranded on the European beaches (EC, 2019). The new measures addressed on derelict fishing gear by imposing the Extended Producer Responsibility (EPR) should ensure an appropriate management by a dedicated waste and recycling stream for the abandoned, lost or disposed of fishing gears (EC, 2019). At international level, the IMO has strengthened the implementation of MARPOL Annex V (IMO, 2018) recently boosted by the new action plan adopted for ships and vessels including measures like the reporting the loss of fishing gear, facilitating the delivery of retrieved fishing gear to shore facilities.

It is broadly assumed that approximately 80% of marine litter is caused by land-based activities (Faris and Hart, 1995; Allsopp et al., 2006)although further research is needed to verify this gross assumption (Jambeck et al., 2015). The relevance of land-based activities on the FML pollution of the study area was relatively low unlike expected. Land-based sources were related to only by over 3.4% of all the litter items (9% of the identifiable items). Caution was taken when attributing litter items to land-based sources due to the difficulties to point out the origin with clarity except of direct littering related to activities on the coast such beach tourism or sewage-related waste. Certain items, in particular, fragments resulting from the disintegration of larger items, can be very hard or even impossible to identify in terms of their initial purpose and possible origin (Veiga et al., 2016). The data show a considerable degree of uncertainty in litter origins since 43.99% could not be attributed directly to a concrete origin, particularly plastic pieces between 2.5 and 50 cm, which account over the 40.46% in number of the total non-sourced items. Plastic objects exposed to solar UV radiation and oxidation are progressively eroded and fragmented by wind, wave or biological action (UNEP and Grid-Arendal, 2016). The fragmentation rates are relatively high on beaches but generally several orders of magnitude smaller for plastics floating in water (GESAMP, 2015; Efimova et al., 2018). However, very limited information is available on the fragmentation process of plastics in the marine environment (Maes et al., 2019) so both local but also remote origins can be attributed to the analyzed plastic fragmented pieces.

Single-use plastics, entering the ocean from multiple sources and pathways, account for 18.5% by number, lower than expected (but still important) contribution comparing to other studies where single-use plastics are by far the biggest contributor to marine litter (EEA, 2018). The intensive cleaning efforts undertaken during spring and summer in the coastal area, an enhanced appropriate waste management mechanism inland, together with the relevance of the fishing activities in the SE Bay of Biscay might have contributed to reduce the presence of these litter items generated at local scale. Despite the percentages, data on litter in the water column and seafloor would help to understand more precisely the sources of marine litter in the SE Bay of Biscay.

Lessons Learned About the Floating Litter Monitoring Strategy

Surface-trawling plankton nets are mostly suited to sample small-sized items (few centimeters in size) because of the sparse distribution and frequency of the large items on the ocean surface and the relatively small area sampled by the plankton nets. Visual observations from vessels are able to cover larger sampling areas; however, semi-submerged macro-litter is often overlooked from visual counts (Galgani et al., 2011). Monitoring FML ideally requires large net openings operated at the sea surface, specific ship equipment and significant dedicated ship time, resulting in higher costs and technical difficulties than visual sampling (Galgani et al., 2013). The present study demonstrates that the adaptation of an existing structure of a small-scale fishing vessel combined with the crew expertise allowed for an extensive and cost-effective collection of FML data in the coastal waters of the SE Bay of Biscay. Indeed, Andrés and Basurko (2020) estimated that the cost associated to the active fishing for (floating) litter activities by the Itsas Belarra ranged between 5 and 8 €/kg. Results are proven to be helpful for FML monitoring programs. However, it is important to note that collection is conditioned by the need of FML removal and the willingness to pay for this service by the local authorities (Andrés and Basurko, 2020). Besides, the efficiency of the operations relies on crew experience gathered over previous years collection. In the study area, the collection of occurrence data on litter windrows is centralized in the "LEMA Tool," a decision-support tool developed during the LIFE LEMA project[2] and currently used by local authorities. LEMA Tool is fed by information provided by the skipper in charge of the collection at sea, who after the sighting of a litter windrow reports the coordinates and the collected weight. Moreover, this tool is being strengthened with complementary approaches like videometry or numerical modeling. In return, LEMA Tool provides decision-aid indicators and alerts to make the collection more efficient regarding the different aspects detailed, from the planning of the collection activities to the data analysis and sharing.

Underpinned by our experience, some general guidelines are proposed to enable the replication of the FML collection and management. The acquisition of information, in collaboration with stakeholders, on the occurrence of litter windrows is key for identifying the best period to undertake the FML collection in the target area. Ideally the data-collection plan should cover different seasons and metocean regimes, although its design is contingent upon the needs of the agents funding the collection and the high retention periods (if known). Likewise, the implementation of an adapted protocol on the regular fishing for litter must be agreed with the competent organizations and fishermen to ensure an adequate collection, sampling and disposal of the litter collected. The engagement of the litter-collecting agent to use a standard protocol for litter collection and data reporting on litter windrows is also an important point. This reporting should include at least location of the litter windrows and weight collected per windrow. Data should serve to support numerical modeling approaches and satellite observations. It is expected that these approaches can build support for the fishing for litter in a near future. While the surface trawling to collect litter, it is important to prevent large organic items from entering the net since these items can easily collapse or damage it. The use of additional fishing gears such as brailers or dipnets is recommended for this purpose. In laboratory, the analysis of a dry fraction of the litter, determining the water content in the sample, is also recommended as a way to normalize data. A 2.47 wet/dry FML litter ratio was estimated in the present study. Finally, sharing and disseminating the information about the cleanup activities is vital to further the knowledge about the formation and persistence of litter windrows as well as to strengthen the collaboration between the different actors of the program.

[2]http://www.lifelema.eu/

Litter Windrows Are Key to Improve the Waste Management in Coastal Environments

The presence of litter windrows is pivotal for the efficient collection of litter. The concentration of the marine litter along the windrows is in fact more relevant than the abundance of marine litter itself for the effective active collection at sea. Without the aggregation resulting from of the windrows, the litter would be scattered, and the collection would be much less efficient. The range estimated by Andrés and Basurko (2020) could be further reduced up to 3–8 €/kg, if a guidance tool was employed by the fishers to make the collection much more efficient. But most importantly, the benefits associated to having a clean sea (without marine litter) are superior to the cleaning cost. This statement has been supported by the analyses of McIlgorm et al. (2011) and more recently by King (2018).

A more effective mitigation strategy addressed on the presence of litter windrows at the coastal area requires further background information about spatial distribution, frequency, persistence or origin of these small-scale ocean processes. Data shown here constitutes a first contribution of these characteristics; nonetheless the knowledge resolving litter windrows formation, lifetimes and factors conditioning the litter loads along these convergence lines requires further research.

CONCLUSION

Plastic pollution is global mounting problem and it demands similarly ambitious actions. While many pictures and videos in the international media show dense rafts of floating litter on the world oceans, research has overlooked this phenomenon so far. References to litter windrows in the research literature are tangential and limited to a few reports (Ryan, 2013; Law et al., 2014). This first descriptive study provides, with unprecedent detail, an observational description of litter windrows in the coastal waters of the SE Bay of Biscay. Litter windrows were usually rectilinear. Longer and less dense windrows may appear in summer. Besides, they often formed further from the coastline during this season. The common findings of small-scale convergence structures in the coastal waters of the SE Bay of Biscay provide, for the first time, enough evidence to support an active fishing for FML. The lack of previous studies of litter windrows does not enable comparisons with other periods or regions. This experience supports the efficacy of the FML mitigation actions carried by the fishing sector in Bay of Biscay, although preventive measurements should be necessarily conducted at the same time. By collecting FML data according to standardized protocols and by sharing them through international databases, fishing vessels adapted to surface litter collection might significantly underpin the development of targeted and effective actions for preventing FML socio-ecological impacts. In the SE Bay of Biscay, sea-based sources represent a significant contribution to FML generation comparing to land-based sources The top litter subcategories were mainly single use and fishing related items, invoking for measurements to reduce the litter generated by the fishing activities. In agreement with previous findings on global scale, plastic was the dominant type of material in the SE Bay of Biscay. Litter windrows in Bay of Biscay presented an opportunity to collect FML in an efficient manner. Furthermore, there remains considerable scope for further improvement of the cleanup effectiveness by increasing our knowledge on the physical processes driving the generation of litter windrows.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/**Supplementary Material**.

AUTHOR CONTRIBUTIONS

IR: sampling characterization, data analysis, and writing up. OB: experimental design, sampling characterization, intellectual contribution, supervision and validation, and review and editing. AR: experimental design, intellectual contribution, supervision and validation, and review and editing. MD: intellectual contribution, review and editing. IG: sampling characterization. AD: intellectual contribution. JM: intellectual contribution. AC: intellectual contribution, validation, and review and editing.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2020.00308/full#supplementary-material

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