CleanAtlantic

Tackling Marine Litter in the Atlantic Area

Investigation of seafloor litter for the presence of Non-Indigenous Species during French annual fisheries surveys in the North Sea, English Channel, Celtic Sea and Bay of Biscay 2021-2022

WP 5.5: Evaluation of marine litter as transport facilitator

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Interreg Atlantic Area European Regional Development Fund
EUROPEAN UNION
Clean Atlantic

WP	5
Action	5
last updated	25/07/2023
version	1
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List of Abbreviations

ATR-FTIR – Attenuated Total Reflectance – Fourier Transform Infrared Spectroscopy

D10 – MSFD Descriptor number 10, “Marine Litter”

MSFD – Marine Strategy Framework Directive

NIS – Non-Indigenous Species

OSPAR - International organisation to prevent pollution of the Northeast Atlantic (OSLO-PARIS)

RV - Research Vessel

Summary

Seafloor litter samples were collected as part of the International Bottom Trawl Surveys in 2021 and 2022. The surfaces of 146 macrolitter items taken from benthic trawl surveys conducted in the North-East Atlantic were examined for the presence of macrofauna, including Non-Indigenous Species (NIS). A total of 145 taxa were recorded, including three NIS (the barnacles *Solidobalanus fallax* and *Austrominius modestus* and the slipper limpet *Crepidula fornicata*).

The three NIS were found exclusively in the English Channel, on litter items likely to have been recently reclaimed from very shallow coastal waters. No NIS were found in the Bay of Biscay, however a large amount of litter from longline fisheries was found to be colonised by diverse sessile communities. Dominant litter plastic types were smooth flexible polyethylene and polyamide – found mostly in the form of monofilament fishing lines.

The results from this study will be pooled with those from a sister study led by Cefas, thus bringing together into a single dataset 251 colonised seafloor litter items. The resulting broad-scale dataset will allow us to compare litter items and plastic types with fouling communities.

Introduction

The role of plastic waste as a dispersal vector for non-indigenous species (NIS) is one of the least studied consequences of plastic pollution at sea (Audrézet et al., 2021). Natural floating debris (e.g. tree trunks, cuttlefish bones, etc.) has always been a transport vector for terrestrial and marine species. However, the explosion in the amount of anthropogenic waste at sea multiplies the possibilities for species dispersal.

To address this lack of information on the subject, in 2023 a team of researchers published a review of existing literature studying the dispersal potential of marine litter as a vector for the introduction and spread of NIS (Mghili et al., 2023). Over the period from 1997 to 2022, 36 publications on the introduction of NIS marine litter were identified, with an increase in the annual number of publications from 2017 onwards. According to the authors, this increase could be linked to the growing amount of plastic debris detected worldwide, which acts as a primary vector but also facilitates the spread of NIS between points of introduction.

Whilst there is a growing body of literature of the role of floating plastic debris as vectors of NIS introductions (i.e. Minchin et al., 2013, Rech et al., 2016), to our knowledge only one study has focused on shallow coastal seafloor debris off the coast of Brazil (Mantelatto et al., 2020). The present study was performed within the framework of the extension of CleanAtlantic Project inside task 5.5 dealing with the role of seafloor Marine Litter as Non-Indigenous Species (NIS) vector. This task is led by ARDITI which is an active member of the OSPAR Intersessional Correspondence on Marine Litter (ICG-ML).

In the previous phase of the project, CEFAS tested a protocol based on the analysis of marine organisms fixed on seafloor litter, to detect whether any potentially invasive NIS were found to be present (Barry et al, 2021). Seafloor litter has been collected during monitoring programmes which have been in place, at both national and international levels, since 2013, based on MSFD TG-ML recommendation (Galgani et al, 2013). A protocol was implemented opportunistically on annual fisheries surveys which use benthic trawls. As Ifremer is in charge of the implementation of this protocol for the French environmental ministry, seafloor litter samples were collected during four benthic trawl surveys: one in 2021 and three in 2022, in the Atlantic area. Here, we examine data from samples collected during these four surveys to evaluate whether, and which type of, seafloor debris play a role in NIS introductions.

Materials and Methods

SAMPLE COLLECTION

In this study, seafloor litter were collected opportunistically during three annual fisheries bottom trawl surveys on the R/V *Thalassa*, in the Atlantic area:

- IBTS (International Bottom Trawl Survey) during winter 2022 (January/February) in the southern North Sea/Eastern Channel (DOI: 10.17600/18001811),
- CGFS (Channel Ground Fish Survey) during early autumn 2022 (September/October) in zones 7d (eastern English Channel) and 7e (western English Channel) (DOI: 10.17600/18001842),
- EVHOE (*EValuation des ressources Halieutiques de l'Ouest Européen*) during autumn 2021 & 2022 (end October, November, early December) in the Bay of Biscay and Celtic Seas (2021 DOI: 10.17600/18001223; 2022 DOI: 10.17600/18001822).

The number of trawls sampled for NIS detection and campaign periods are shown in Table 1 ; Haul locations in Figure 1.

Table 1 : Survey periods and number of trawls sampled

Surveys	Start date	End date	Trawl numbers
EVHOE21	22/20/2021	06/12/2021	22
IBTS22	17/01/2022	19/02/2022	7
CGFS22	15/09/2022	19/10/2022	10
EVHOE22	21/10/2022	05/06/2022	28

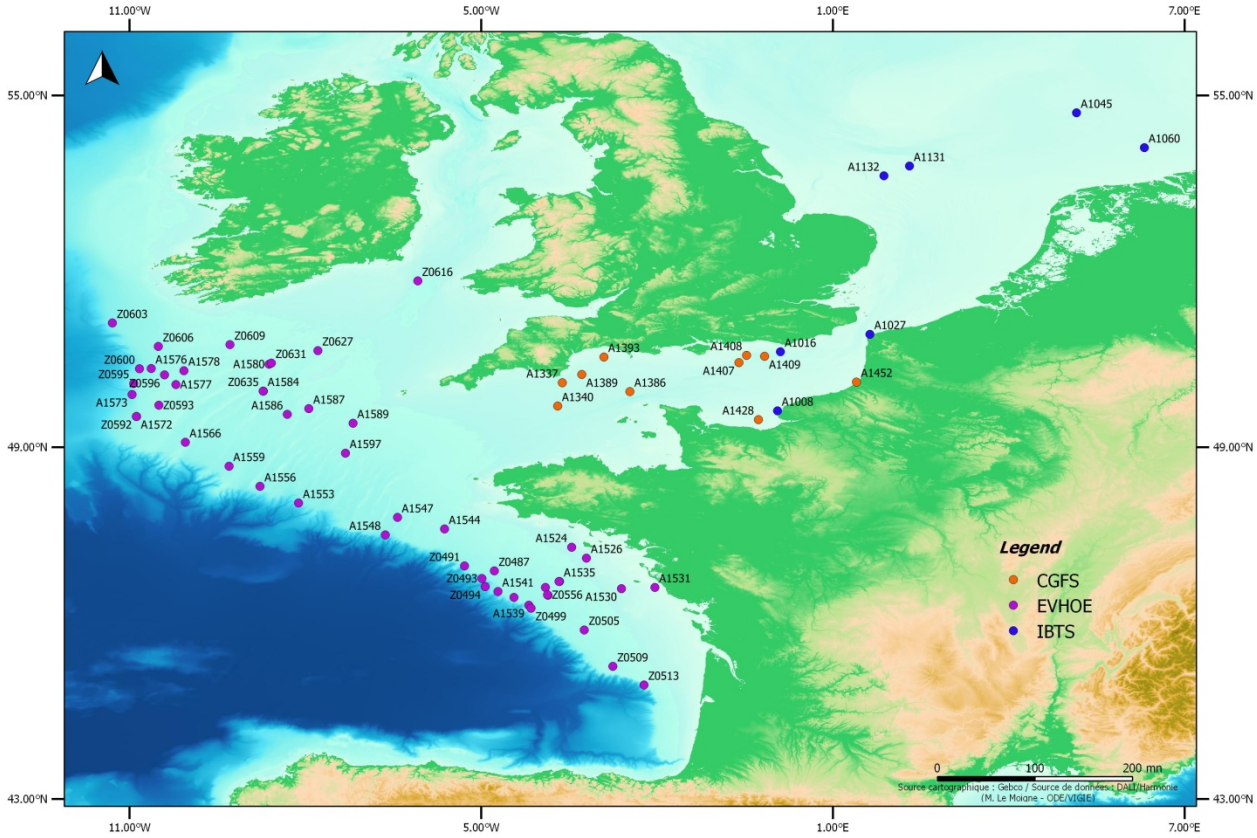

Figure 1 : Map of sampling locations where benthic litter was retained for attached organism analysis.

These demersal fish stock assessment campaigns use a GOV36/47 trawl (Figure 2). Haul duration is approximately 30 minutes at a speed of five knots. Depending on the quantity of fish detected with the sonar and suspected to be caught, the haul duration may be under 30 minutes.

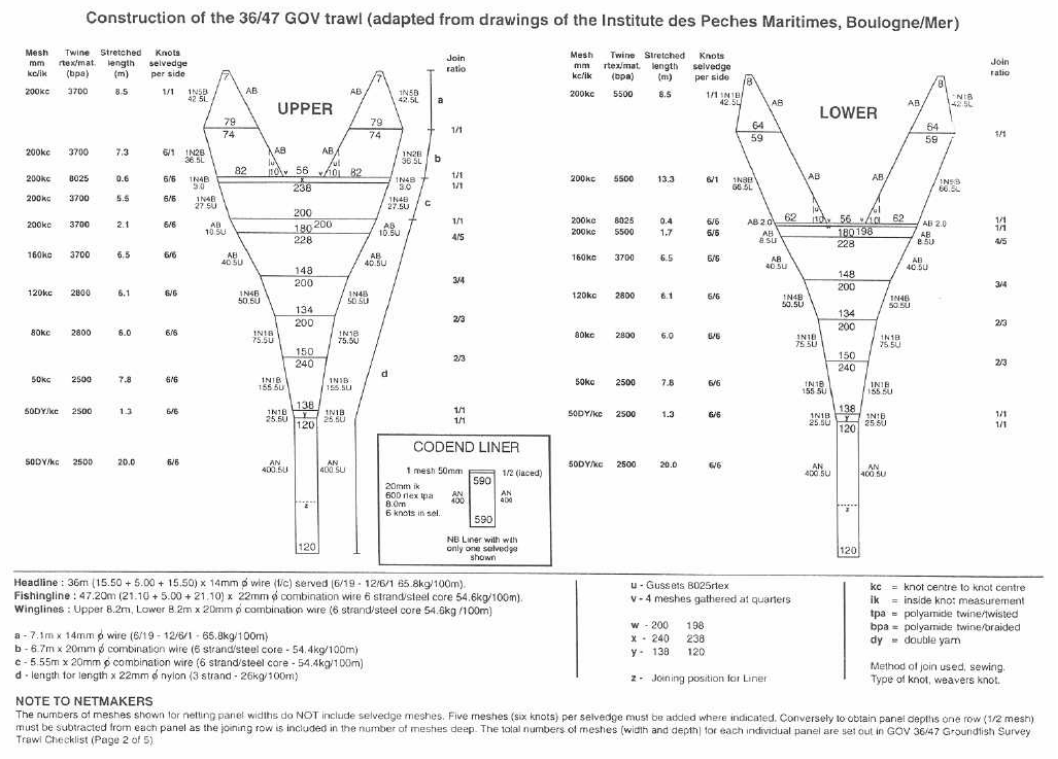

Figure 2 : GOV36/47 trawl features

This study added to the existing monitoring surveys under the MSFD (Marine Strategy Framework Directive) by sampling all, or part of, the marine litter caught by the trawl which are habitually discarded after noting the relevant properties for D10 monitoring (see Annex 1). Since the trawl is working immediately once immersed, it must be noted that some litter items might come from the water column and not exclusively from the sea bottom.

PROCESSING OF LITTER ITEMS

Overall, 146 items of marine litter with epifaunal coverage were separated from benthic trawl material: 10 from CGFS, 16 from IBTS, 44 from EVHOE 2021 and 76 from EVHOE 2022.

When analyzing the trawl contents, seafloor litter was processed on-board according to the MSFD marine litter protocol: they were photographed, sorted, classified, counted and weighted (see Annex 1). They were recorded in the TUTTI application and then in the DALI Database which was created specifically for Marine Litter data.

Samples chosen for this study were frozen onboard the research vessel at -20°C and then transferred and stored in the DYNECO-LEBCO laboratory in the same conditions.

In addition to the categorization of the litter by the MSFD nomenclature, a characterization of the hardness (solid versus soft), roughness (1 smooth, 2 lined, 3 rough), dimensions (length and width) and chemical nature of the polymers were performed (see Polymer Analysis section), in order to match the protocol

developped by CEFAS during the first phase of the CleanAtlantic Project (Barry et al., 2021). Each litter item was also photographed (Figures 3-6).

Figure 3 : EVHOE 2021 – Z0499 marine litter trawl content

Figure 4 : EVHOE 2021 – Z0487 marine litter trawl content

Figure 5 : CGFS 2022 – A1428 marine litter trawl content

Figure 6 : CGFS 2022 – A1407 marine litter trawl content

PROCESSING OF TAXA

Fixed fauna identification was carried out whenever possible by visual inspection for organisms of 0.5 mm size or more. Many taxa requiring smaller morphological details for identification or even requiring a dissection were examined under a Zeiss Stemi 2000-C stereomicroscope and an Olympus BX-40 microscope. A reference collection of at least one individual or colony fragment in good condition were collected (about 134 taxa). Identifications were made down to the lowest taxonomic level when possible (128 species on 145 taxa).

Figure 7: Close-up of dried litter items after fixed fauna identification and before polymer analysis.

Regardless the size of the items, the abundances for each non-colonial taxa was precisely determined. For all colonial taxa (such as Bryozoa or Hydrozoa) their occurence was recorded as 'Present'. If possible or

necessary a comments category giving more information, such as the potential poor morphological conditions of the specimen preventing a species-level ID, were noted. An estimated surface area (in percentage) for each taxa was also noted (0%, 5%, 10% and then by 10s until 100 %).

POLYMER ANALYSIS

All plastics items were analyzed by Fourier Transform Infrared (FTIR) spectroscopy using the sampling methodology of Attenuated Total Reflectance (ATR). ATR-FTIR measurements were then performed with a Thermo IS50 infrared spectrometer using ZnSe 9 bounding module. ATR-FTIR transmittance spectra were recorded at room temperature in the midIR range (400–4000 cm^{-1}). Each spectrum was averaged over 50 scans with a resolution of 4 cm^{-1}. A background scan was recorded prior to measurement and subtracted from the sample spectra. Polymer identification was made using a home made database thanks to a Rshiny script with a HQI = 0.75. Quality control was carried out with the analysis of a polyethylene (PE) reference material before each batch. Note that many litter items were composed of entangled synthetic rope or netting. Whenever possible each distinctive material was separated and analysed through the ATR-FTIR, leading to 316 polymer identifications for 146 litter items.

Results

BENTHIC ORGANISMS

863 benthic organisms were observed on the samples. 145 taxa, divided into 17 classes and 10 phyla were identified. Of these, 128 were identified to species level (see Annex 2). In terms of species richness, the three most diverse phyla were bryozoans (34%), annelids (17%) and mollusks (14%) (Figure 8).

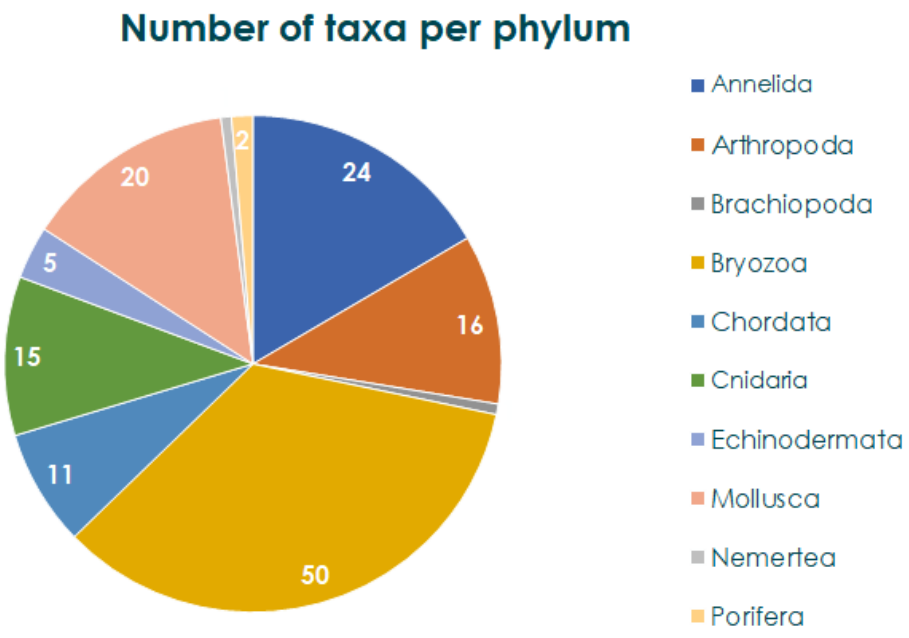

Figure 8: Number of taxa identified per phylum on seafloor litter samples

Three species of NIS were detected on six different litter samples from the English Channel (Figures 9 & 10).

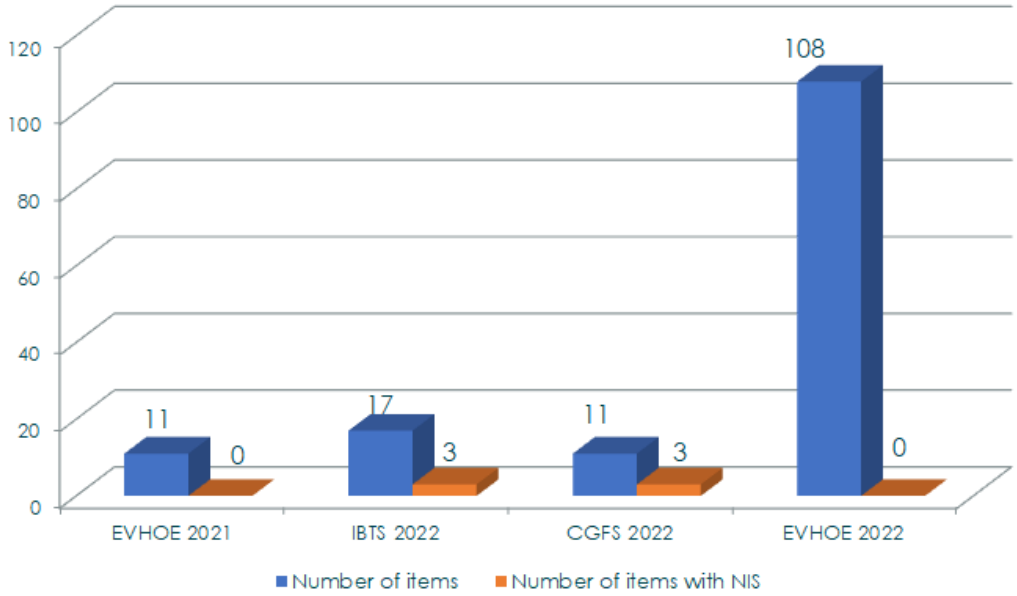

Figure 9: Number of litter items collected per IBTS campaign. Total numbers of items are in blue; items colonised by NIS are in orange

The Australian barnacle *Austrominius modestus* were found attached to a PVC fishing glove and an O-ring (Polyethylene + polypropylene) ; the warm water barnacle *Solidobalanus fallax* was found on plastic sheeting; and the slipper limpet *Crepidula fornicata* was found on three separate PVC fishing gloves. No NIS were identified on material from the Bay of Biscay (2021).

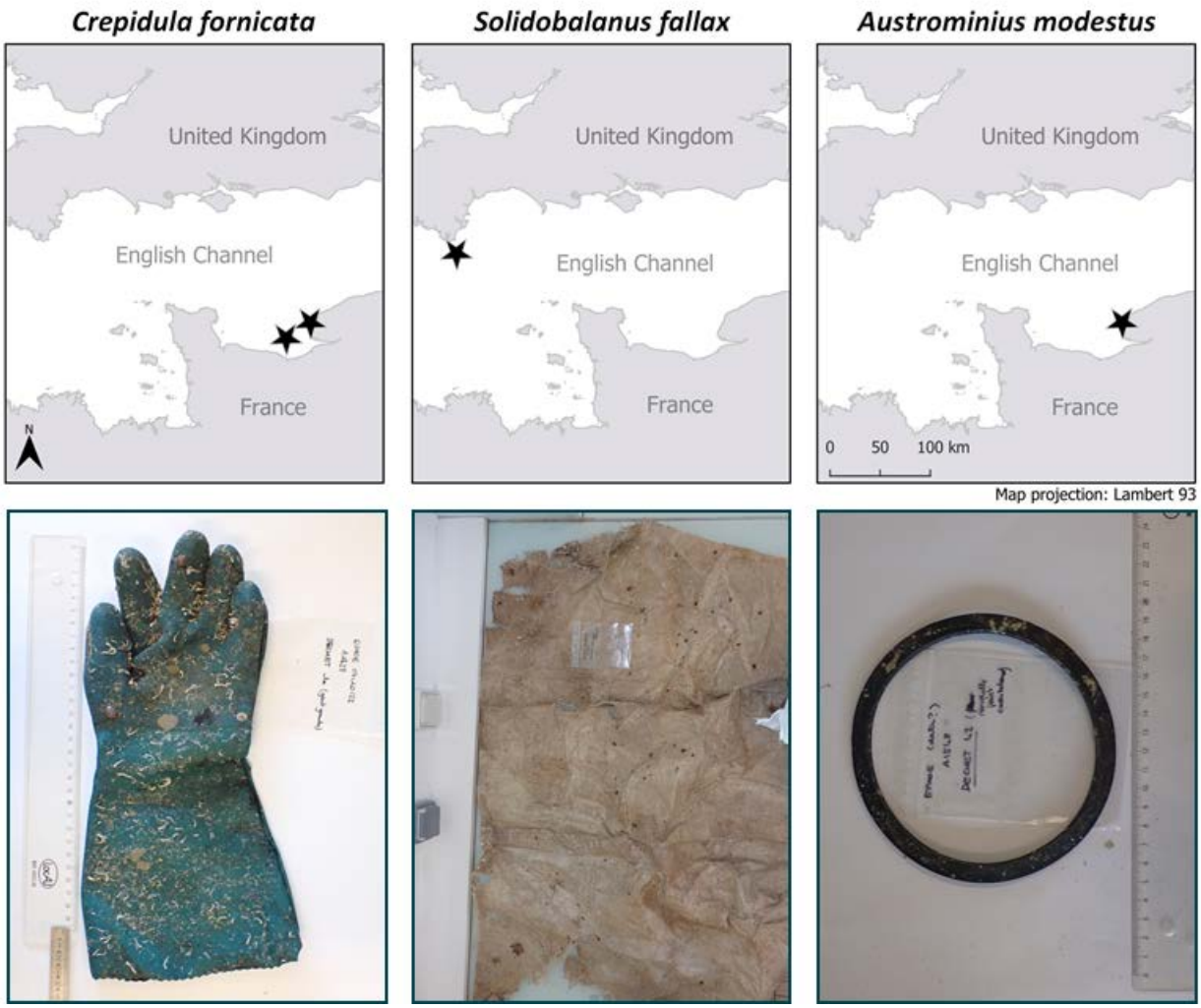

Figure 10: Location of seafloor litter items colonised by NIS, with photographs of litter items. ***A****. PVC fishing glove on which 12 C. fornicata individuals were found* ***b****. Plastic sheeting (PPRF) with one S. fallax individual* ***c.*** *Rubber ring (PESF + PPSF) on which nine A. modestus were found. Note that C. fornicata and A. modestus were also found on PVC fishing gloves not pictured here.*

POLYMER ANALYSIS

316 samples were run through the AT-FTIR. This number exceeds the 146 litter samples collected, due to fact many of them – roping and netting – were made up of several plastics. Most of the analysed items of plastic macrolitter were composed of smooth flexible Polyethylene (PESF - 87 samples) or Polyamide (nylon) (PASF – 85 samples) (Figure 11).

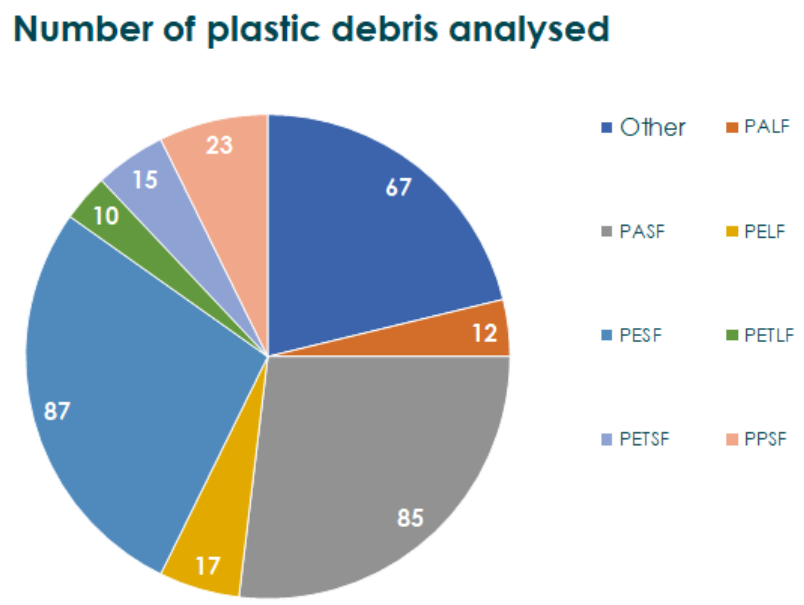

Figure 11: Proportion of different plastic types in the 316 samples analysed through AT-FTIR (PALF -Polyamide-Lined-Flexible ; PASF - Polyamide Smooth Flexible; PELF - Polyethylene Lined Flexible; PESF – Polyethylene Smooth Flexible; PETLF – Polyethylene terephthalate Lined Flexible; PETSF - Polyethylene terephthalate Smooth Flexible; PPSF – Polypropylene Smooth Flexible)

Out of the 172 items PASF & PESF plastic items collected, 147 items (85%) were debris from fishing activities: bits of netting and longlines from the hake (*Merluccius merluccius*) fishery in the northern Bay of Biscay.

Discussion

Every year, millions of tonnes of plastic end up in the world's oceans (Jambeck et al., 2015). The Organisation for Economic Co-operation and Development's report "Global Plastics Outlook: Scenarios for Action to 2060" indicates that in 2019 global plastic consumption was 460 million tonnes, with 353 million tonnes of plastic waste produced (OECD, 2022). According to figures from the European Parliament, between 4.8 and 12.7 million tonnes of these plastics end up in the oceans every year. Plastics currently account for more than 85% of total marine waste (UNEP, 2021).

With such alarming figures it is evident that opportunities for marine organisms to colonize plastic debris have substantially increased over the past few decades. There are still however gaps of evidence and a need for better understanding about the 'life cycle' of litter items when they reach the sea bottom. Studies recovering fouled litter from the open ocean are limited, and to our knowledge only one study has evaluated the state of colonization of submerged litter, off the coast of Brazil through SCUBA-diving (Mantelatto et al., 2020). The process and pathways involved for items to become marine litter are unclear, as are the time frames and the process that entraps the items on the seafloor. A better understanding into this will help us appreciate more about the findings in this report and future studies. A consensus is also needed for a standardised litter classification combined with polymer identity (De-la-Torre et al., 2023).

Bryozoans were the dominant phylum found on seafloor debris, both in the present study (bryozoans comprised 34% of species richness), and in the sister Cefas study (25% of species richness). The other main taxonomic phyla in this study were annelids (17%) and molluscs (14%). Some litter items were colonised by diverse fouling communities, with a record diversity reached on a piece of polypropylene plastic sheeting, hosting 24 species, including the warm-water barnacle *Solidobalanus fallax, s*ampled in september 2022 in the western English Channel.

The main fouling taxa are the same as those identified in a recent review by Mghili et al (2023), where 67 NIS associated with marine litter were identified in the scientific literature. The main taxonomic groups associated with marine litter were arthropods (29%), molluscs (23%), bryozoans (19%) and annelids (7%). The study also showed that the Atlantic contains more NIS associated with marine litter than other regions (36 species). The Pacific Ocean (17 species) and the Mediterranean Sea (16 species) also contain a high number of NIS associated with marine litter. This is of interest, since in French marine regions the total number of marine NIS is far higher in the Mediterranean (239) than in the Bay of Biscay (185) or the Northern Sea (168) (Massé et al., 2023).

Out of 64 hauls, only five trawled seafloor debris were colonized by three NIS: two arthropods (the barnacles *Solidobalanus fallax* and *Austrominius modestus*) and one mollusk (the slipper limpet *Crepidula fornicata*). All three of these hauls were located in the English Channel. It is interesting to note that in the parallel study led by Cefas, the exact same three species NIS were identified and sampled, albeit in the Irish Sea. No NIS were found in the North Sea by Cefas, or in the Bay of Biscay by Ifremer.

Although NIS only represent a small fraction of the species richness in this study, we cannot conclude that marine litters are not a NIS vector. Firstly several taxa, not found in this study, have already been discovered along the UK coasts transported *via* marine litter (e.g. Barry et al., 2023; Holmes et al., 2015). Secondly, focusing on marine litter from trawling surveys means we sampled only the seafloor fraction of

the litter present in the marine environment. Thirdly, because our study focuses on seafloor marine litter, we do not give an exhaustive overview of the potential role marine litter plays in NIS dispersal, compared to if all others compartments were studied (floating or beached litter).

Future Work

These results will be pooled with those from Cefas carried out between 2020 and 2023, which cover the North Sea, Irish Sea and English Channel. By combining the results from both French and English fisheries and environmental monitoring programmes, the joint study will cover three of the five OSPAR regions and bring into a single dataset 251 colonised seafloor litter items.

This broad-scale joint Ifremer/Cefas dataset will allow us to compare litter items and polymer types with fouling communities. This work will be carried out during 2024, and will allow a more in-depth investigation of whether there is a pattern to the distribution of fouling communities on seafloor litter; either geographical or driven by the characteristics of the litter (i.e. texture and composition). The use of the FTIR will allow us to establish species preferences for different plastic substrate chemical characteristics, a recommendation from a recent review (De-la-Torre et al., 2023). Once published, the data will be archived in DeNIS – a Global Database on Marine Debris and Non-Indigenous Species (https://www.denis-db.com/)

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Acknowledgements

The authors wish to thank the chief scientists on the IBTS cruises: François Garren, Didier Leroy and Arnaud Auber as well as the crew of the R/V Thalassa. The authors also wish to thank the Detection, Sensor and Measures Laboratory (LDCM) at Ifremer for their advice and for the use of the ATR-FTIR. Peter Barry from Cefas, for the shared protocol and interesting discussions, is also thanked. Finally, a special thanks to the leaders of this CleanAtlantic project task: Joao Canning-Clode and Joao Monteiro from MARE-Madeira, who carry out this issue of marine litter as transport facilitators for NIS at EU level.

ANNEX 1

Fiche Macrodéchets - Campagnes IBTS, CGFS, EVHOE (mise à jour avril 2018)

Campagne : Date : _/__/_ N° trait :

Responsable (nom/Unité):

Catégorie de tailles
A: <5*5cm = 25 cm²
B: <10*10 cm = 100 cm²
C: <20*20 cm = 400 cm²
D: <50*50 cm = 2500 cm²
E: <100*100 cm = 10000 cm² = 1 m²
F: >100*100 cm = 10000cm² = 1m²

Catégorie des déchets	Nombre	Poids (g)	Taille (A,B,C,D,E,F)	Commentaire Organismes attachés : oui/non Taxonomie / photo
01 - Plastique / Bouteille / A1 _ L1b				
02 - Plastique / Morceaux / A2				
03 - Plastique / Sacs / A3 _ L1a				
04 - Plastique / Bouchons, couvercles / A4				
06 - Plastique / Lignes de pêche (monofilament)/ A6				
06 - Plastique / Lignes de pêche (emmêlé) / A6 _ L1g				
07 - Plastique / Cordage synthétique / A7				
08 - Plastique / Filets de pêche / A8 _ L1f				
09 - Plastique / Attaches de câble / A9				
10 - Plastique / Bande de cerclage / A10				
11 - Plastique / Caisses et conteneurs/ A11				
68 – Plastique / Couches / A12				
69 – Plastique / Serviette hygiénique, tampons / A13				
12 - Plastique / Autres / A14_L1j				
27 - Métal / Boîtes de conserve / B1 _ L3b				
28 - Métal / Cannettes / B2 _ L3a				
29 - Métal / Objets liés à la pêche / B3 _ L3f				
30 - Métal / Batterie / B4				
31 - Métal / Appareils / B5				
32 - Métal / Pièces de voiture / B6				
33 - Métal / Cables / B7 _ L3e				
34 - Métal / Autres / B8				
38 - Caoutchouc / Bottes / C1				
39 - Caoutchouc / Ballons / C2				
40 - Caoutchouc / Bobines (pêche) / C3				
41 - Caoutchouc / Pneu / C4 _ L2a				
42 - Caoutchouc / Gants/ C5				
43 - Caoutchouc / Autres / C6				
46 - Verre_céramique / Bocal / D1				
47 - Verre_céramique / Bouteille / D2 _ L4a				
48 - Verre_céramique / Morceau / D3				
49 - Verre_céramique / Autres / D4				
54 - Produits naturels / Bois (travaillé) / E1				
55 - Produits naturels / Corde / E2 _ L5c				
56 - Produits naturels / papier, carton / E3 _ L7				
57 - Produits naturels / Bois recyclé, palettes / E4_L6				
58 - Produits naturels / Autres / E5				
60 - Divers / Vêtements, Chiffons / F1				
61 - Divers / Chaussures / F2				
62 - Divers / Autres / F3_L9				

ANNEX 2

	PHYLUM	# of litter items where species was observed
	Annelida	
1	Ampharetidae	1
2	Amphinomidae	1
3	Aspidosiphon muelleri	3
4	Branchiomma bombyx	1
5	Branchiomma sp	1
6	Chaetopteridae	1
7	Chaetopterus variopedatus	2
8	Eulalia aurea	1
9	Eumida sanguinea cplx	1
10	Eumida sp	2
11	Eunice cf pennata	12
12	Filograna implexa	3
13	Harmothoe fraserthomsoni	11
14	Harmothoe sp	1
15	Hydroides norvegica	61
16	Nereididae	1
17	Phyllodocidae	1
18	Placostegus tridentatus	3
19	Polycirrini	1
20	Pterocirrus macroceros	1
21	Sabella pavonina	2
22	Sabella sp	4
23	Sabellaria spinulosa	1
24	Sabellidae	1
25	Serpula sp	1
26	Serpula vermicularis	24
27	Serpulidae	1
28	Spirobranchus lamarcki	5
29	Spirobranchus triqueter	6
30	Syllidae	2
31	Syllis sp	3
32	Terebellidae	3
33	Thelepus sp	3
34	Thelopodinae	3
35	Vermiliopsis infundibulum	3
	Arthropoda	**61**
36	Anthura gracilis	6
37	Aoridae	1
38	Austrominius modestus	2
39	Balanus balanus	1
40	Balanus crenatus	6
41	Cymodoce truncata	1
42	Galathea dispersa	4
43	Gammaropsis maculata	2
44	Gnathia oxyuraea	1

	Arthropoda continued	
45	Lepas (Lepas) anatifera	1
46	Lepas (Lepas) pectinata	1
47	Perforatus perforatus	1
48	Pisidia longicornis	13
49	Scalpellum scalpellum	11
50	Solidobalanus fallax	1
51	Sunamphitoe pelagica	1
52	Verruca stroemia	8
	Brachiopoda	**3**
53	Terebratulina retusa	3
	Bryozoa	**292**
54	Alcyonidiidae	1
55	Alcyonidium cf albidum	2
56	Alcyonidium parasiticum	6
57	Alcyonidium sp	2
58	Alderina imbellis	3
59	Ammatophora nodulosa	1
60	Amphiblestrum flemingii	1
61	Annectocyma major	6
62	Arachnidium hippothooides	1
63	Bicellariella ciliata	4
64	Bryozoa sp	2
65	Buskea dichotoma	5
66	Callopora dumerilii	4
67	Calloporoidea	2
68	Cellaria salicornioides	16
69	Cellaria sinuosa	1
70	Cheilostomatida	2
71	Chorizopora brongniartii	2
72	Cribrilaria venusta	1
73	Crisia aculeata	1
74	Crisia sp	2
75	Diplosolen obelium	11
76	Disporella hispida	21
77	Einhornia crustulenta	1
78	Electra pilosa	13
79	Entalophoroecia deflexa	1
80	Escharella immersa	2
81	Escharella ventricosa	1
82	Escharina vulgaris	2
83	Fenestrulina malusii	1
84	Haplopoma graniferum	1
85	Haplopoma impressum	1
86	Hemicyclopora multispinata	1
87	Herentia hyndmanni	2

	Bryozoa continued	
88	Microporella ciliata	6
89	Omalosecosa ramulosa	1
90	Oncousoecia dilatans	5
91	Parellisina curvirostris	7
92	Pentapora foliacea	1
93	Plagioeciidae	1
94	Puellina sp	4
95	Pyripora catenularia	46
96	Reteporella couchii	4
97	Schizomavella (Schizomavella) auriculata	3
98	Schizomavella (Schizomavella) hastata	2
99	Schizomavella (Schizomavella) hondti	5
100	Schizomavella (Schizomavella) linearis	18
101	Schizomavella cf (Schizomavella) gautieri	2
102	Schizomavella cristata	1
103	Schizoporella sp	2
104	Schizoporella unicornis	1
105	Schizoporellidae	1
106	Tervia irregularis	2
107	Tricellaria inopinata	1
108	Tubulipora liliacea	5
109	Tubuliporidae	4
110	Turbicellepora avicularis	47
	Chordata	**38**
111	Ascidia mentula	2
112	Ascidia sp	1
113	Ascidiella aspersa	1
114	Ascidiella scabra	17
115	Ascidiella sp	2
116	Botryllus schlosseri	1
117	Ciona intestinalis	2
118	Didemnidae	2
119	Diplosoma sp	1
120	Molgula sp	1
121	Molgulidae	3
122	Pyura sp	1
123	Pyura tessellata	3
124	Pyuridae	1
	Cnidaria	**138**
125	Abietinaria abietina	2
126	Actinauge richardi	14
127	Actiniaria	11
128	Alcyonium digitatum	4
129	Campanulariidae	1
130	Caryiophyllia sp	2
131	Caryophyllia (Caryophyllia) smithii	6
132	Diphasia margareta	1
133	Epizoanthidae	11

	Cnidaria continued	
134	Hormathia coronata	7
135	Hormathiidae	3
136	Hydrallmania falcata	5
137	Hydrozoa	30
138	Lafoea dumosa	14
139	Sagartia sp	1
140	Sertularella gayi	5
141	Sertularella sp	1
142	Sertularella tenella	15
143	Sertularia cupressina	1
144	Sertulariidae	1
145	Urticina felina	3
	Echinodermata	**31**
146	Asterias rubens	1
147	Asteroidea	1
148	Echinidea	1
149	Ophiactis balli	19
150	Ophiocomina nigra	2
151	Ophiothrix fragilis	3
152	Ophiothrix luetkeni	4
	Mollusca	**125**
153	Aequipecten opercularis	3
154	Anomia ephippium	1
155	Calliostoma granulatum	1
156	Capulus ungaricus	1
157	Crepidula fornicata	3
158	Doridiidae	1
159	Emarginula fissura	3
160	Gastropoda	1
161	Heteranomia squamula	56
162	Hiatella arctica	23
163	Kellia suborbicularis	1
164	Leptochiton asellus	1
165	Mimachlamys varia	2
166	Modiolula phaseolina	15
167	Musculus subpictus	1
168	Mysia undata	1
169	Neopycnodonte cochlear	6
170	Ocenebra erinaceus	1
171	Palliolum incomparabile	1
172	Pteria hirundo	1
173	Rossia macrosoma	1
174	Steromphala cineraria	1
	Nemertea	**1**
175	Nemertea	1
	Porifera	**6**
176	Porifera	5
177	Suberites sp	1