CleanAtlantic

Tackling Marine Litter in the Atlantic Area

Spatial and temporal variability in floating litter in North Sea / English Channel and Bay of Biscay / Celtic Sea

2015-2020

WP 4.1 : Floating litter assessment

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Introduction

The implementation of the MSFD monitoring program has been carried out in 2015 based on TGML recommandations (Guidelines 2013). In French Atlantic Area, Floating Marine MacroLitter (FMML) were monitored during yearly french fishing stock assessment surveys on the R/V "Thalassa" vessel (Baudrier et al, 2018):

- IBTS (International Bottom Trawl Survey) during winter (january/february) in South North Sea/Eastern Channel,
- CGFS (Channel Groung Fish Survey) during early Automn (september/october) in zones 7d (Easter English Channel) et 7e (Western English Channel),
- PELGAS (*Petits Pélagiques Gascogne*) during spring time (April/May) in Bay of Biscay
- EVHOE (*Evaluation des ressources halieutiques de l'ouest européen*) during automn (end october, november, early december) in Bay of Biscay and Celtic Sea.

FMML observations have been deployed during PELGAS surveys since 2003, IBTS surveys since 2007, CGFS surveys since 2014 and EVHOE surveys since 2009. In this study, we have choosen to analyse FMML data collected from the beginning of the implementation of the monitoring program that means since the applying of a common monitoring protocole during those surveys in 2015 untill last surveys in 2020.

The MEGASCOPE protocol (Doremus and Van Canneyt, 2015) from UMS PELAGIS Institute is applied by observers on board. This protocol aims to observe Marine Mammals, Seabirds, Human activities and floating marine macrolitter from the upper bridge or inside the bridge depending on weather conditions.

Two surveys have no data because of their cancellation: EVHOE 2017 due to a vessel damage and PELGAS 2020 due to COVID-19 sanitary situation.

Protocol and data collection

Protocol

Sighting data on FMML were collected on the onboard R/V “Thalassa” during IBTS, CGFS, PELGAS and EVHOE campaigns between 2015 and 2020 applying the MEGASCOPE protocole (Doremus and Van Canneyt, 2015) implemented by the Observatoire PELAGIS.

FMML observers carried out data collection following a distance sampling protocol (Buckland et al. 2015). Survey effort (vessel speed > 8 knots), observation conditions (glare, cloud, cover, sea state, etc) and the precise GPS location of each sighting are recorded from dawn till dusk. Along a transect, a leg corresponds to a portion of effort surveyed in the same observation conditions: whenever the latter changed (e.g. a change in ship activity, sea state or observer team) a new leg started. Two observers were operating each on one side of the upper bridge (16 m above sea level) or inside the bridge (14 m above sea level) when outdoor conditions deteriorated. Observers searched for marine litter with naked eyes within an angle of 90° from the side to the bow. Binoculars were only used for identification. A leg was thus at most one-hour long and observation bouts for any observer lasted at most two hours followed by a one-hour break.

For each sighting, the observer estimated the (radial) distance with a graduated stick calibrated to the observer's height, to measure distances from the horizon when held at their eye-level. Each stick was observer specific, and had two scales: one for observing from the upper bridge and the other for observing inside the bridge. The angle of each sighting was estimated with an angleboard.

During the observation, records of floating litter focused on the determination of the material (e.g. plastic, Wood,…) and the size class (<10cm; 10 to 50cm; > 50cm) (Table 1):

Table 1 : FMML categories and size

		Size
FISHTR	Fishing trash (net part, buoy,…)	<10 cm 10 à 50 cm > 50cm
IRONTR	Iron trash	
PLASTR	Plastic trash	
POLYTR	Polystyrene trash	
TRASH	trash (plastic, wood, oil)	
WOODTR	Unnatural wood	
OIL	Oil slick	

The position of the litter is also noticed by the GPS position of the vessel, the angle between the direction of the vessel and the litter, as well as the distance between the observer and the litter. This protocol requires two observers on the vessel to cover the entire area (Figure 1).

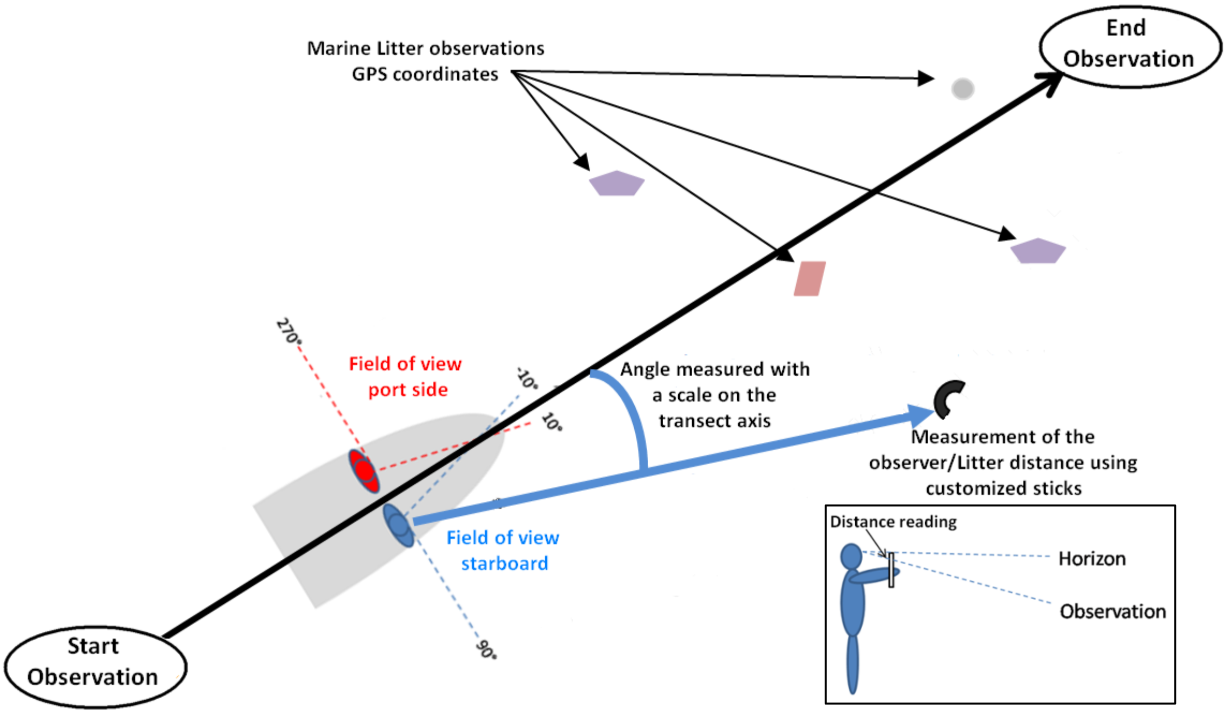


Figure 1 : Megascope protocol to observe the floating macrolitter

Number of legs and Litter observations

The table below shows that PELGAS is the cruise with the most important **number of legs** with more than 60% each year; followed by CGFS campaign with meanly 25% per year; then EVHOE campaigns with meanly 19% and finally IBTS with meanly 8% of the legs yearly.

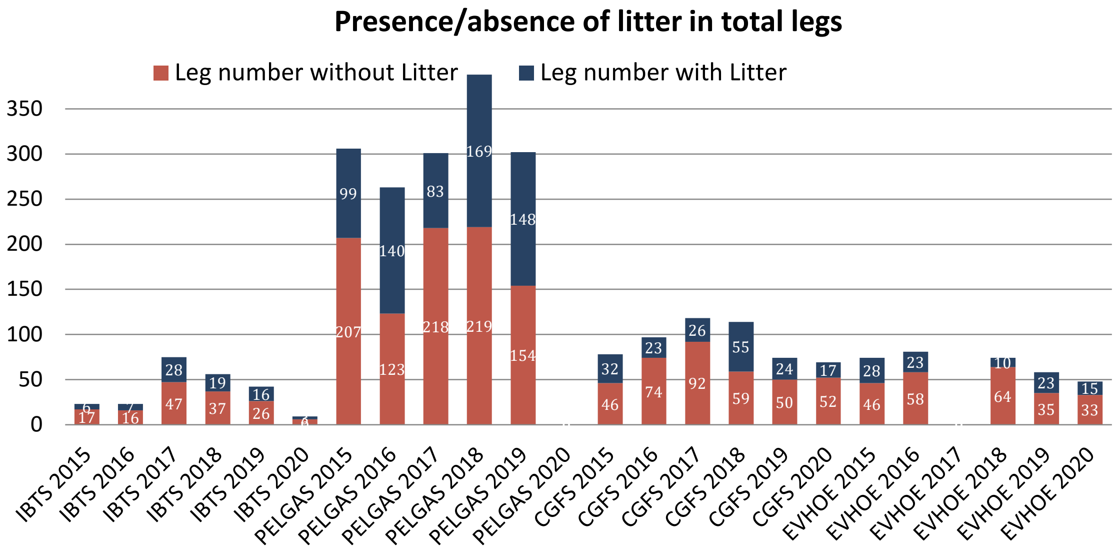
Table 2 – Number and percentage of legs per campaign and per year

	IBTS (Winter)	PELGAS (Spring)	CGFS (summer/automn)	EVHOE (automn)	Total
2015	23 *(4,8%)*	306 *(63,6%)*	78 *(16,2%)*	74 *(15,4%)*	**481 *(100%)***
2016	23 *(4,9%)*	263 *(56,7%)*	97 *(20,9%)*	81 *(17,5%)*	**464 *(100%)***
2017	75 *(15,2%)*	301 *(60,9%)*	118 *(23,9%)*	*0*	**494 *(100%)***
2018	56 *(8,9%)*	388 *(61,4)*	114 *(18%)*	74 *(11,7%)*	**632 *(100%)***
2019	42 *(8,8%)*	302 *(63,5%)*	74 *(15,5%)*	58 *(12,2%)*	**476 *(100%)***
2020	9 *(7,1%)*	*0*	69 *(54,8%)*	48 *(38,1%)*	**126 *(100%)***

To have comparable results with the Spanish Institute of Oceanography (EIO), also involved in this project, only observations realized under "good" weather conditions, i.e. Beaufort lower than 5, are analysed. Thus, **2 673 legs out of 3 529 were kept** in the dataset.

Considering the number of litter **observations**, Table 3 shows the number of legs per campaign, with and without litter.

Table 3 : Number of litter observation per campaign and per year



Litter occurence is encountered in 37% of the 2673 legs analysed in this study.

DATA COLLECTION

Data curated, validated and archived into the MEGASCOPE database managed by the Observatoire PELAGIS (Dorémus 2021) were provided to Ifremer for their storage in DALI (Data LItter) Database. This Database was developed in 2018 at Ifremer to host D10 MSFD data collected during monitoring programs on beach litter, seafloor litter, floating macrolitter, floating microlitter, litter ingested by marine organisms and litter inducing entanglement/stranglement/covering on marine organisms. Data from the different monitoring programs are thus stored with the same structuration/referential. This harmonisation facilitates transmissions to european databases (DATRAS, EMODnet,…). Moreover the storage in a database allows data securisation as they are saved every day in a data center.

Calculation

The area observed at each leg is variable depending on several factors, such as the duration of the leg or the observation conditions. In order to obtain comparable results, litter abundance need to be calculated with the length and width of each leg. Their calculation is detailed in sections below.

Leg length calculation

When the length of the leg is not available in DALI database, this parameter is calculated from start and end coordinates of the leg according to the equation:

$$L_i = R \times arccos\left(sin(y_i^{start}) \times \sin(y_i^{end}) + cos(y_i^{start}) \times cos(y_i^{end}) \times cos(x_i^{end} - x_i^{start})\right)$$, with:

- L_i, leg length for leg *i*;
- *R*, the conventional radius of the Earth, equal to 6 378 137 m;
- y_i^{start} and y_i^{end}, the start and end latitudes in radians for leg *i*;
- x_i^{start} and x_i^{end}, the start and end longitudes in radians for leg *i*.

Leg width calculation - Distance Sampling method

Based on the MEGASCOPE protocol described in § 2 and in Authier et al. (2018), the observed Effective Strip Width (ESW) is estimated by the "distance sampling" method (Buckland et al., 2004). For each group of surveys, i.e. IBTS, PELGAS, CGFS and EVHOE, the detection function is fitted with the “ds” function of the “Distance” package (V1.0.2; Miller et al., 2019) in R© software (V4.0.3), allowing the calculation of the effective half-width of the transects.

Beaufort, expressed as an integer number between 0 and 8, and the position of the observer (the upper bridge or the bridge) both affect the probability of detection. To avoid the bias introduced by bad weather conditions (*e.g.*, reduction of visibility and consequently the capability of sightings) and to have comparable results with the IEO, also involved in this project, only observations realized under “good” weather conditions, *i.e.* Beaufort lower than 5, are analysed. Regarding the position of the observer, this information is included in the model as a detection covariate. Thus, two ESW are estimated per survey group, excepted for EVHOE because no litter was never observed from the bridge.

Legs with only one observer (7.56 %) have been kept, even if for some surveys and some years, they could have an impact on the width estimation.

For each observation, the distance x_j between the litter *j* and the direction of the boat is calculated according to equation:

$$x_j = l_j \times \left|\sin(\hat{A}_j)\right| \text{with:}$$

- l_j, the distance between the observer and the litter *j*;
- $\hat{A}_j$ the angle between the direction of the boat and the litter *j*.

Table 4 : Effective half-width (ESW/2)

Survey	Observer position	Effective sampling half-width (m)
IBTS	Bridge	182.44
IBTS	Upper bridge	219.82

PELGAS	Bridge	173.38
PELGAS	Upper bridge	124.18
CGFS	Bridge	258.24
CGFS	Upper bridge	185.35
EVHOE	Bridge	No litter observation
EVHOE	Upper bridge	170.55

The result (table 4) shows an effective half-width smaller for PELGAS survey, even though it occurs in spring time where weather conditions should be better than during the other surveys. No explanation can be given in this first analyze.

Density calculation

For each leg, litter density has been calculated according to the following equation:

$d_i = \frac{D_i}{L_i \times ESW_{s[i\,],Pos[i]}}$, with:

- d_i, litter density for leg *i*;
- D_i, litter number for leg *i*;
- L_i, leg length for leg *i*;
- $ESW_{s[i],Pos[i]}$, effective strip width for survey *s* and observer position *Pos* of leg *i*.

Abundances have been calculated for:

- the eight following types of litter:
  - Plastic unspecified,
  - Fishing litter
  - Polystyrene,
  - Unnatural wood,
  - Metal,
  - Oil slick,
  - Litter unspecified,
  - Total amount of litter;

- the four following size classes:
  - <10 cm,
  - 10 to 50 cm,
  - >50 cm,
  - unspecified size.

Since the number of legs can be very disparate from one survey to another and then to avoid bias, the annual means of total litter densities have been calculated as the annual mean of the means per survey:

$\bar{M}_y = \frac{\sum_{S=1}^{S_y} \bar{M}_{y,s}}{S_y}$, with:

- $\overline{M}_y$, the annual mean of litter densities for year *y*;
- S_y, survey number for year *y*;
- $\overline{\mathrm{M}}_{\mathrm{y,s}}$, the annual mean of litter densities for year y and survey s.

Study areas

SOUTH OF NORTH SEA AND ENGLISH CHANNEL

As described in Gerigny *et al*, 2018, many human activities in different sectors, including shipping and fishing, are present in this area. English channel and North sea is one of the busiest maritime areas in the world with 20% of world traffic due to the presence of the North Sea shipping rail which supplies ports of Dunkerque, Calais, Le Havre and Rouen, but also the main European ports such as Rotterdam, Antwerp, Zeebrugge and Hamburg. Maritime transport contributes significantly to the 30% of litter (including container loss) of maritime origin (Mongruel *et al*, 2019 ; UNEP, 2005). Fishing and shellfish farming activities are also very active with 11% of the french companies (Mongruel *et al*, 2019). They may also represent an significant source of litter thrown in this region.

This region has few large cities, tourism is limited, but nevertheless makes its mark on the coastline. Two remarkable industrial zones are present, the first located in the Pas-de-Calais (Boulogne and Dunkerque) and the other located at the mouth of the Seine (Rouen and Le Havre). These industries can generate microlitter (pellets) which are plastic granules of industrial origin used as raw material and which are less dense than sea water, giving them a significant floating capacity. Two important rivers flow into this region : the Seine river with its mouth at Le Havre city and the Somme river, with a much smaller flow, whose mouth is in the Bay of Somme. The catchment area of the Seine is very extensive, highly populated and supports multiple activities generating litter (Gerigny *et al*, 2018).

The western part of English Channel and North Sea is under strong tidal influence with strong alternating currents and a maximum tidal range of more than 7 m in Brest to nearly 15 m in the Norman-Breton Gulf. Its openness to the open sea makes it sensitive to large-scale circulation. The northern coasts of Brittany are dominated by a general current which runs along the coasts and mainly oriented from west to east. It flows up to the north in the eastern part to the North Sea (Lazure and Desmare, 2012).

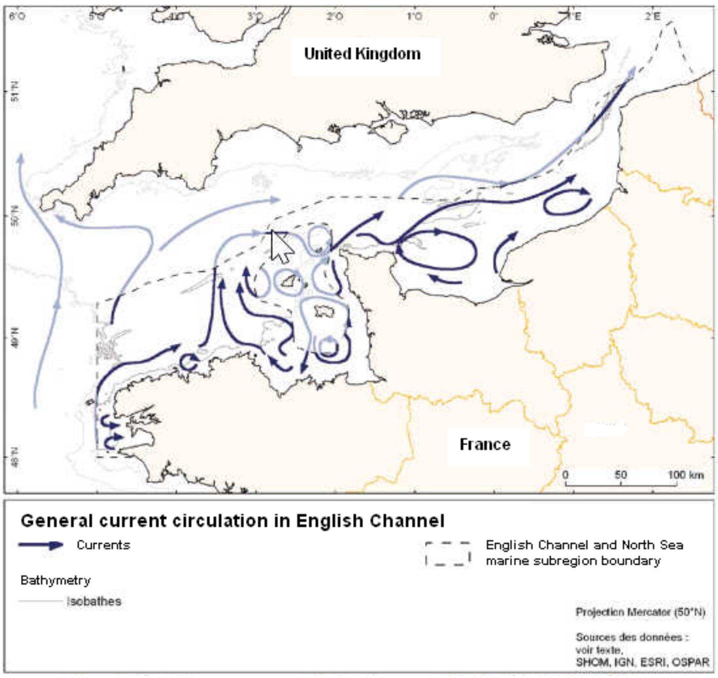


Figure 2 : Currents general circulation in the English Channel and South of North Sea (source Lazure and Desmare, 2012) from Gerigny et al, 2018

BAY OF BISCAY AND CELTIC SEA

Maritime traffic is relatively active without being intense, with 15% of national freight traffic passing through the ports of this region in 2015 (Mongruel et al, 2019). The three major ports - Nantes/Saint-Nazaire, La Rochelle and Bordeaux - concentrate 87% of the total activity of this region, with two other ports being secondary -Lorient and Bayonne-. Some of these ports have exchanges with the large North Iberian ports -Bilbao, Santander, Gijón and A Coruña- (Gerigny et al, 2018). Maritime transport contributes significantly to the 30% of litter (including container loss) of maritime origin (Mongruel et al, 2019; UNEP, 2005)

Tourism and the various associated nautical activities are highly developed along the entire coastline of Brittany, Pays de Loire and Occitania regions, as well as on the nearby Spanish coasts - Basque Country, Cantabria and Asturias -. A strong fishing activity also characterizes the waters of the Bay of Biscay, where Spanish and French fleets meet.

The Bay of Biscay borders the French and Spanish coasts. Several rivers flow into it, the main ones on the French side, are the Loire, the Garonne, the Dordogne, the Charente and the Adour, and about fifteen short torrential rivers come down from the Spanish mountains. The main wind regime is westerly with frequent strong winds. The continental shelf is wide in the North and in the center, but it is cut in the South by two submarine canyons approaching the coast (gouf de Cap-Breton and canyon du Cap-Ferret) in which litter can accumulate (Galgani et al., 2000).

Currents on the continental shelf exhibit strong seasonality. They have been schematized by Lazure and Desmare, in the MSFD initial evaluation in 2012 (Figure 3). In autumn, the Bay of Biscay is subject to a large cyclonic gyre, and on the continental shelf, the current is oriented northwest. In winter, the currents remain predominantly directed to the north and the Portuguese current is responsible for large inflows of water masses into the southern Bay of Biscay (from November to April). In spring, the currents are gradually oriented towards the South, to reverse in summer and are mostly directed to the South under the influence of a prevailing northwest wind.

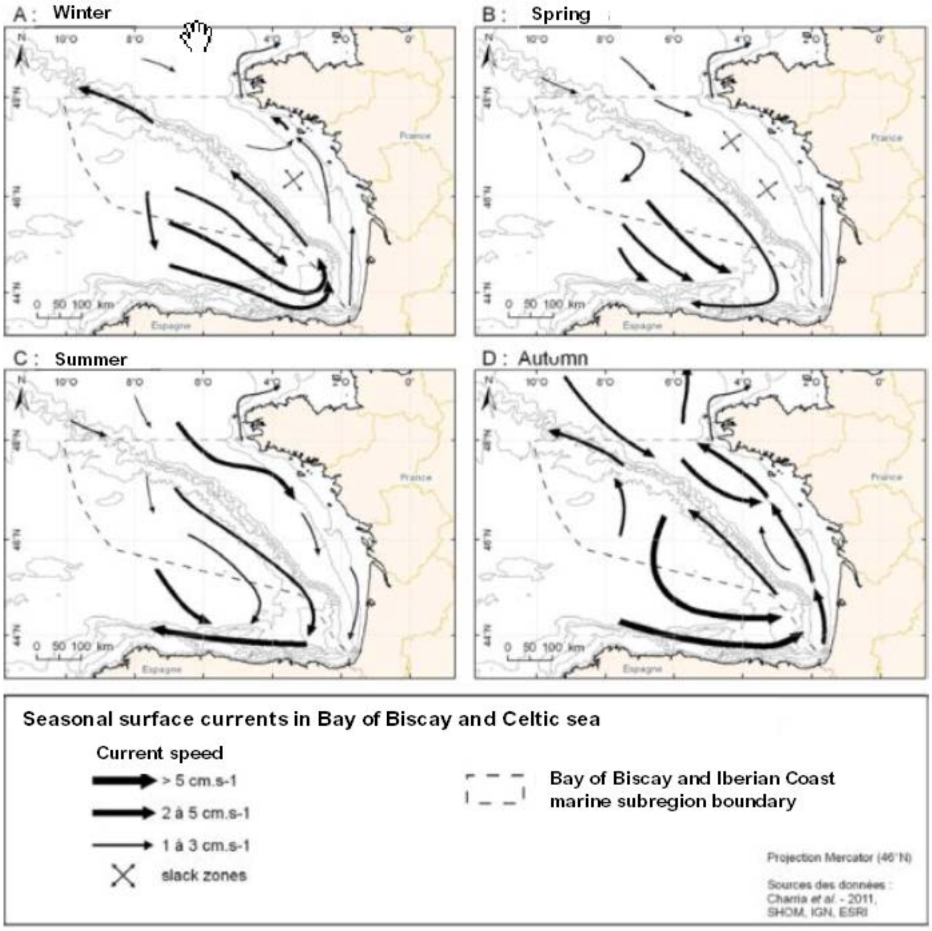


Figure 3 : Seasonal Surface currents on Bay of Biscay and Celtic Sea (source Lazure and Desmare, 2012) from Gerigny et al, *2018*

Results

TYPES OF LITTER OBSERVED

The seven types of floating litter – Plastic unspecified, Fishing litter, Polystyrene, Litter unspecified, Unnatural Wood, Metal, Oil slick - are expressed in Figure 4 as density percentages according to the total quantity of litter collected for each survey.

Plastic unspecified is the most common litter type with an average part of 73.8% for all the cruises. The Rank of the other types was changing depending on the cruises.

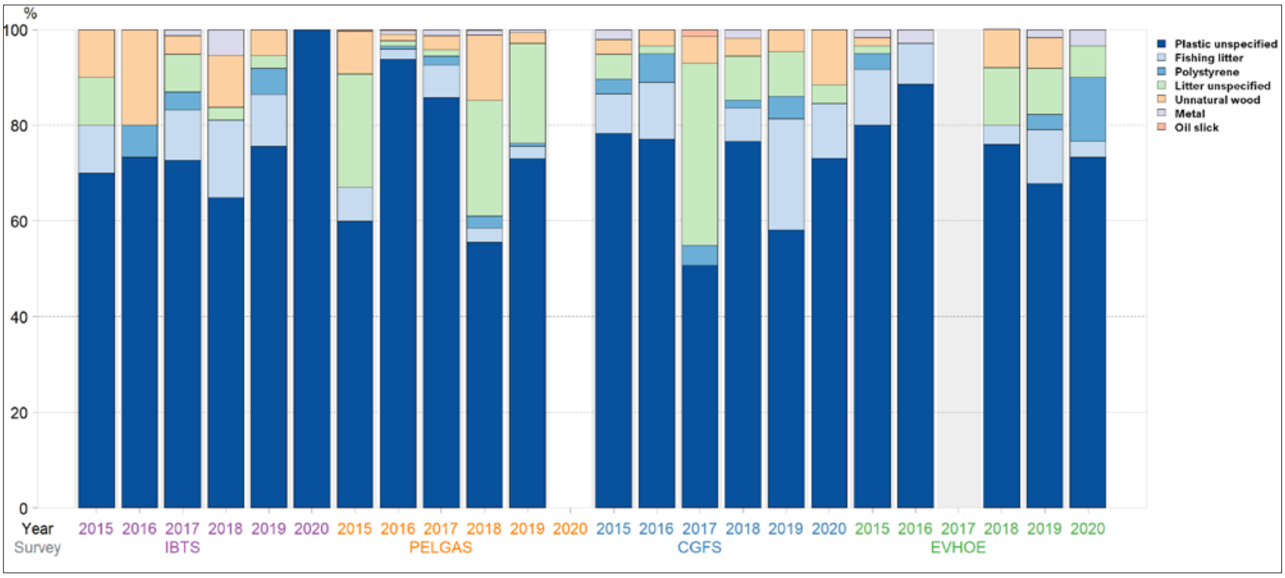
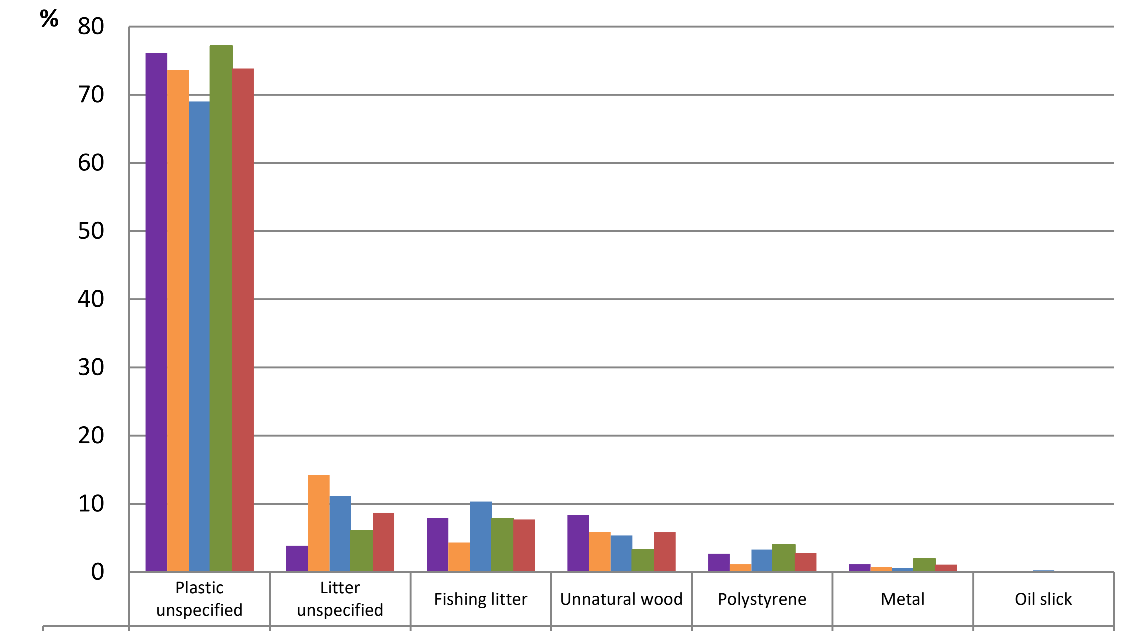


Figure 4 : Percentage of the different type of floating litter collected during IBTS, PELGAS and CGFS and EVHOE surveys from 2015 to 2020

Far behind plastic litter, the second most type observed is "**Litter unspecified**" in PELGAS (14.2%) and CGFS (11.2%) surveys, whereas it was "**Unnatural Wood**" (8.4%) in IBTS surveys and "**Fishing litter**" (7.8%) in EVHOE surveys (Figure 5). The third one is "**Fishing litter**" in CGFS (10.3%) and IBTS (7.9%), whereas it was **Litter unspecified** (6.1%) in EVHOE and "**Unnatural Wood**" (5.8%) in PELGAS surveys. "**Metal**" and "**Oil slick**" were always the two less abundant types of litter with averages at respectivly 1% and less than 0.1% for all the cruises.



	Plastic unspecified	Litter unspecified	Fishing litter	Unnatural wood	Polystyrene	Metal	Oil slick
IBTS	76,1	3,9	7,9	8,4	2,7	1,1	0,0
PELGAS	73,6	14,2	4,3	5,9	1,1	0,7	0,2
CGFS	69,0	11,2	10,3	5,4	3,3	0,6	0,2
EVHOE	77,1	6,0	7,8	3,2	4,0	1,9	0,0
TOTAL	73,8	8,7	7,7	5,8	2,8	1,1	0,1

Figure 5 : Percentage of the various types of floating litter collected during IBTS, PELGAS and CGFS and EVHOE surveys betweend 2015 and 2020

Size classes of floating litter

Except for IBTS 2015 where sizes were not recorded, as a consequence of inexperience of the observers during the first survey, litter between 10 and 50 cm were the most commonly observed sizes.

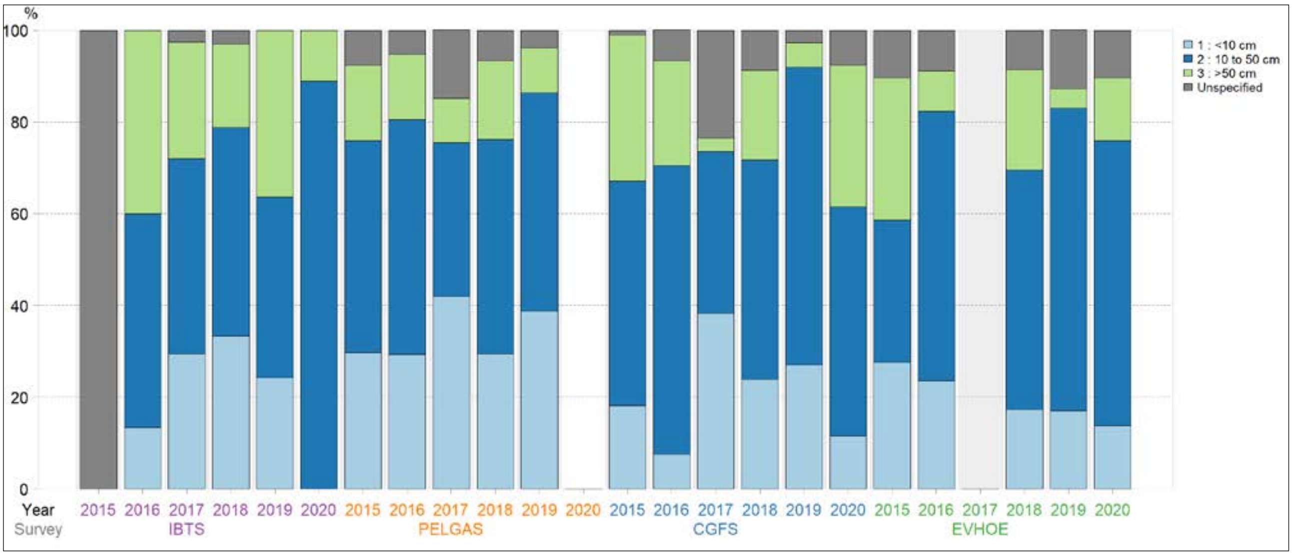
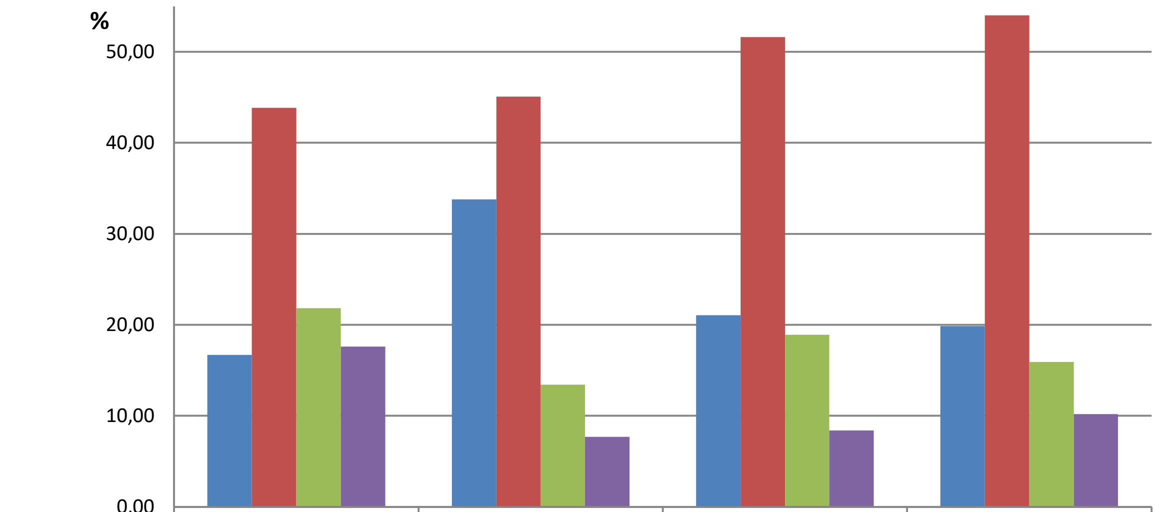


Figure 6 : Percentages of the various litter size classes as recorded per survey (IBTS, PELGAS, CGFS, EVHOE) and per year (from 2015 to 2020)

Litter less than 10 cm were also largely observed during PELGAS surveys, with approximately 33% of the total, whereas usually at less than 21% of the observations (Figure 7). The question of favourable weather and light conditions in spring time for the detection of smaller litter may be asked at this step but no answer is available for instense.

A greater number of litter > 50 cm were also observed during the IBTS campaigns. In that case, bad weather and light conditions in winter time may be also an hypothese to avoid observation of smaller litter. Another explanation may be the important maritime traffic discharging in English Channel/North Sea larger objects.



	IBTS	PELGAS	CGFS	EVHOE
<10 cm	16,71	33,79	21,07	19,86
10 to 50 cm	43,85	45,08	51,63	54,01
>50 cm	21,83	13,44	18,90	15,93
Unspecified	17,62	7,69	8,41	10,19

Figure 7 : Percentage of various size classes of litter in relation to the cruise

Size classe from 10 to 50 cm represents 50.6% of the observations, then size classe <10cm 23.5%, litter >50cm has been observed at 18.7%. Finally, 7.1% are not specified (Figure 8). Years 2017 and 2020 have not the same profil as the other years, probably due to the absence of 2 surveys: EVHOE in 2017 and PELGAS in 2020.

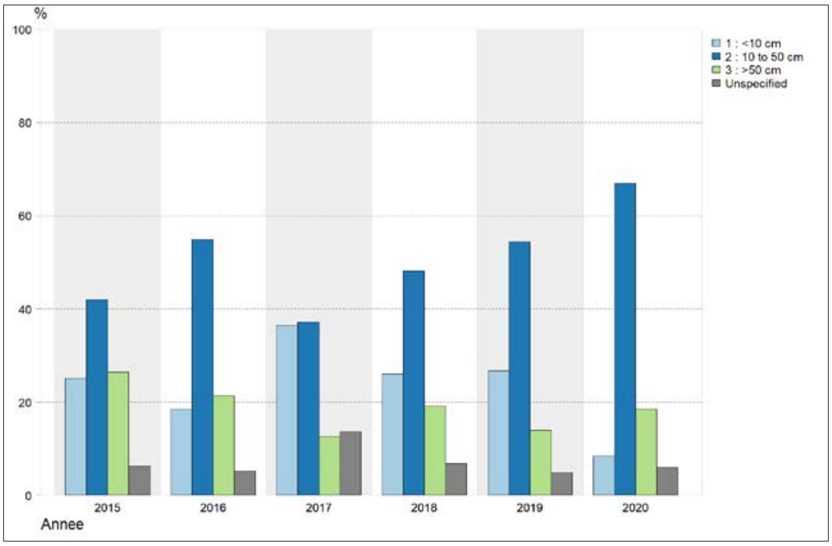


Figure 8 : Annual variations of different size classes of floating litter (by percentage and from 2015 to 2020)

INTER-ANNUAL VARIATIONS

Litter abundances were between 0 and 1.32 unit/km² in IBTS surveys, between 0 and 102.8 unit/km² in PELGAS surveys, between 0 and 5.94 unit/km² in CGFS surveys and between 0 and 2.70 unit/km² in EVHOE surveys. Highest densities were found during the PELGAS surveys, especially in 2016 and 2019 (102.8 and 50.68 respectively). These surveys were characterized by a large number of legs (around 310 each year compared to 90 in CGFS, 70 in EVHOE and 40 in IBTS) with a more important variability. The causes of these observations may be due to the spring season for these survey as EVHOE surveys take place also in the Bay of Biscay but don't show such amount of litter densities. It may also come from the calculation of the distance sampling. Indeed, the widths of the leg of this campaign are less wide than in the other campaigns. Further investigations need to be led.

Repartition of leg densities seems to follow the seasons and then the meteorological conditions with less observations in winter (IBTS), an important amount in spring (PELGAS), a decrease at the end of summer and beginning of autumn (CGFS) and again a decrease at the end of autumn (EVHOE).

Annual mean abundances were found between 0,03 ±0,06 and 0,15 ±0,25 units/km² in IBTS surveys, between 0,16 ±0,37 and 1,48 ±7,19 units/km² in PELGAS surveys, between 0,08 ±0,16 and 0,43 ±0,88 unit/km² in CGFS surveys and finally between 0,06 ±0,23 and 0,18 ±0,42 in EVHOE surveys.

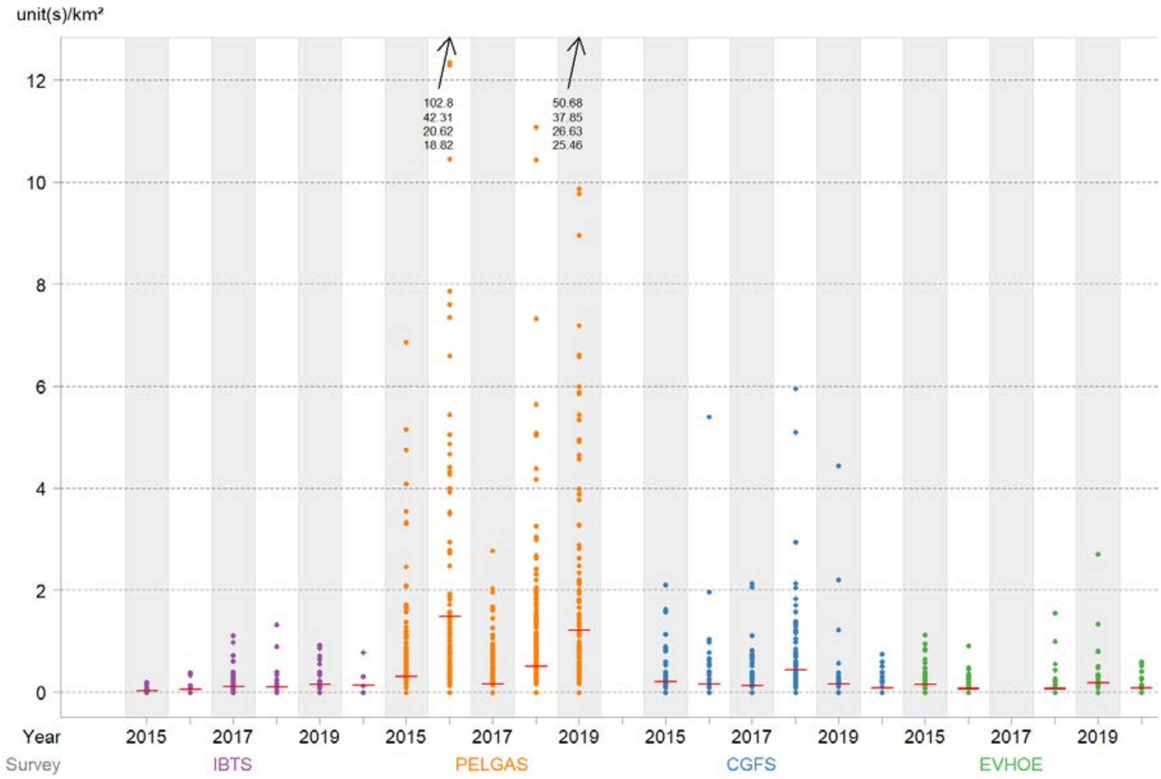


Figure 9 : Interannual variation in litter densities (red bars for the mean values) by year and by cruise

As explained in Density calculation section, since the number of legs may largely vary from one survey and possibly generate bias, calculation of annual means of total litter densities were related to densities have been calculated as the annual mean of the means per survey (Figure 10).

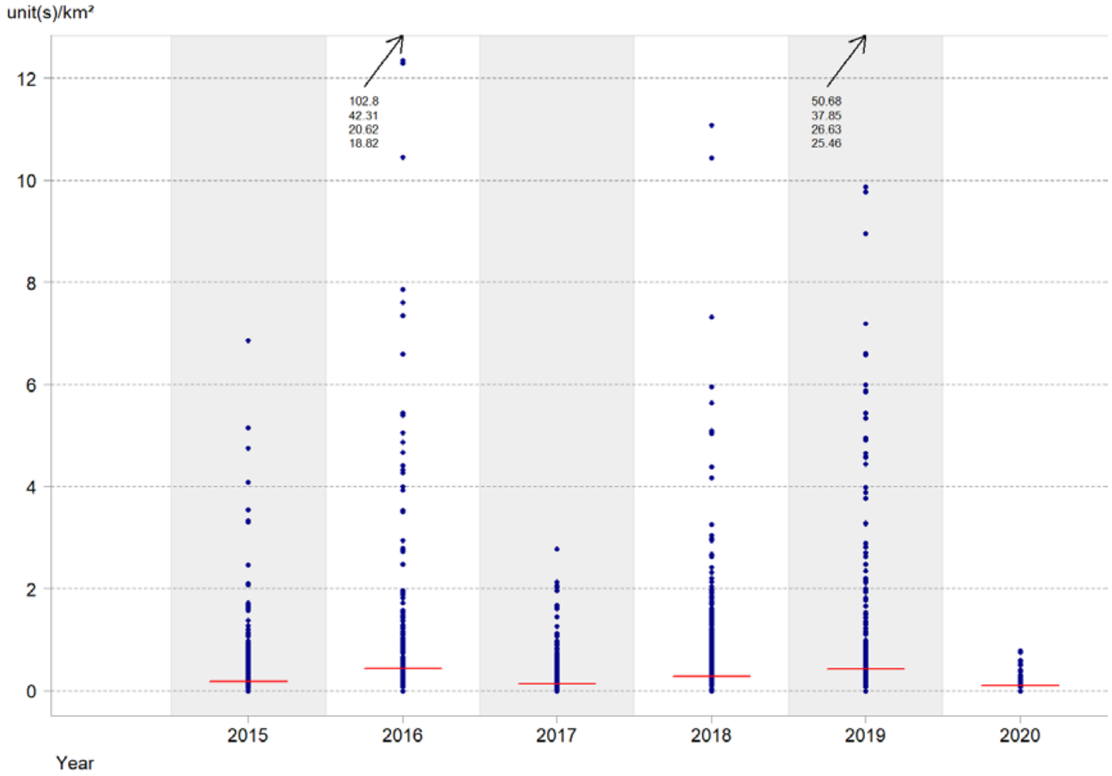


Figure 10 : Interannual variation in weighted means of litter densities for all surveys

The highest weighted means were observed in 2016 and 2019 with respectivly 0.44 and 0.43 units/km². These two years correspond to two very active years for PELGAS in terms of litter abundance, indicating that PELGAS design of the survey influences the results. This was confirmed in 2020 when this campaign was cancelled due to COVID-19, resulting in both a lower annual mean and variability of densities.

SPATIAL VARIATIONS

Maps for each surveys have been created for the period between 2015 to 2020 taking into account the maximum density encountered.

In south of North Sea and English Channel, IBTS cruise (Figure 11) showed a lower abundance of litter than in CGFS cruise (Figure 12) with a maximum value of 1.32 litter/km² south of Boulogne/Mer near the mouth of La Canche River whereas the maximum for CGFS is 5.94 litter/km² in the mouth of the Orne River and not far from the mouth of the Seine river.

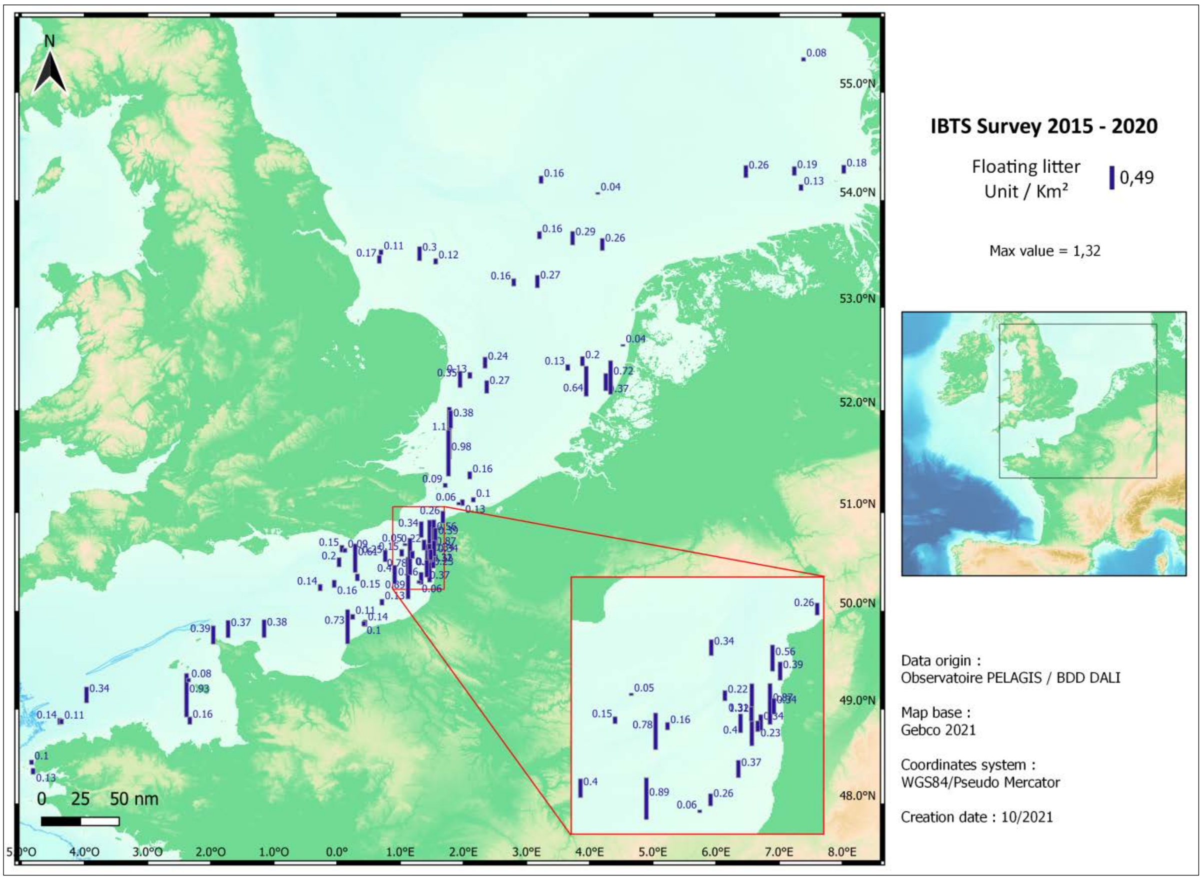


Figure 11 : Litter abundance in IBTS campaigns 2015-2020

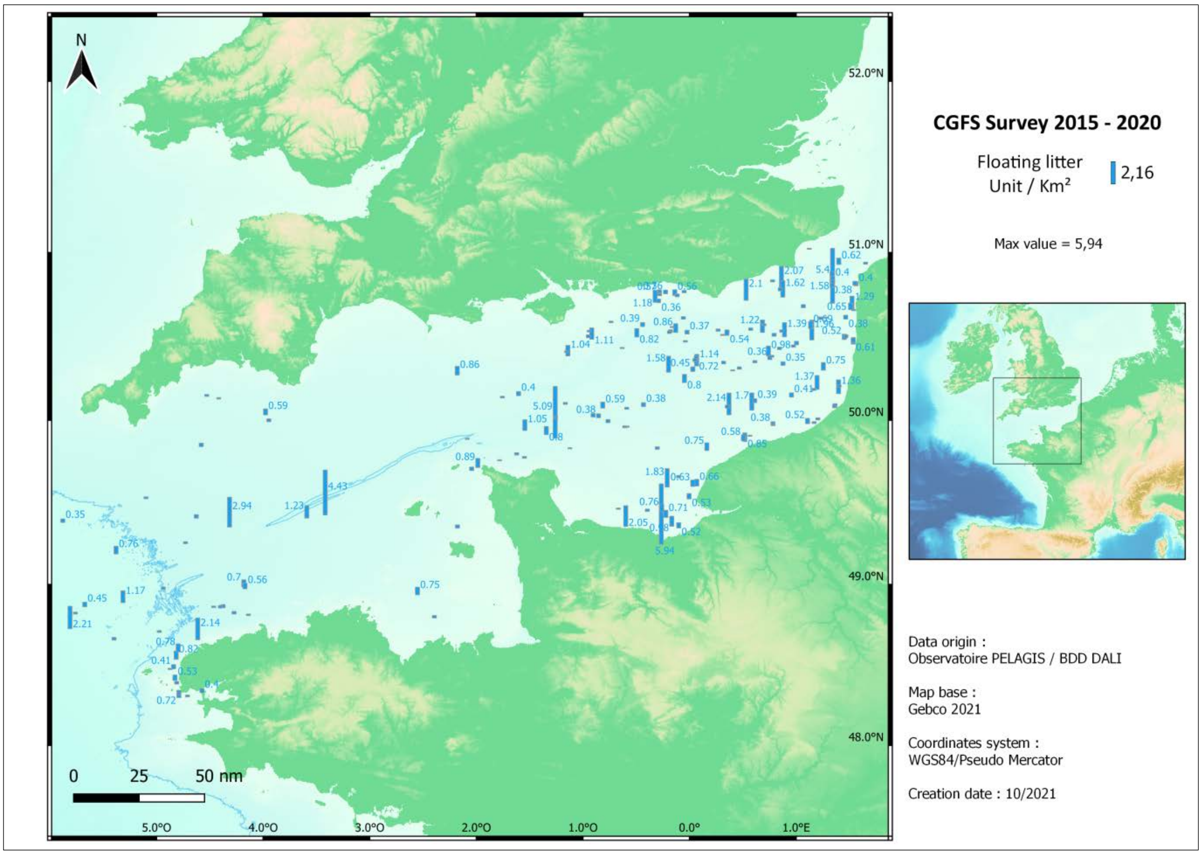


Figure 12 : Litter abundance in CGFS campaigns 2015-2020

In Bay if Biscay and Celtic sea, PELGAS cruise (Figure 13) showed a greater abundance than the EVHOE cruise (Figure 14). Maximum values, 102.8 litter/km² during PELGAS cruise and 2.7 litter/km² during EVHOE cruise, are both off the Gouf of Capbreton, not far from each other.

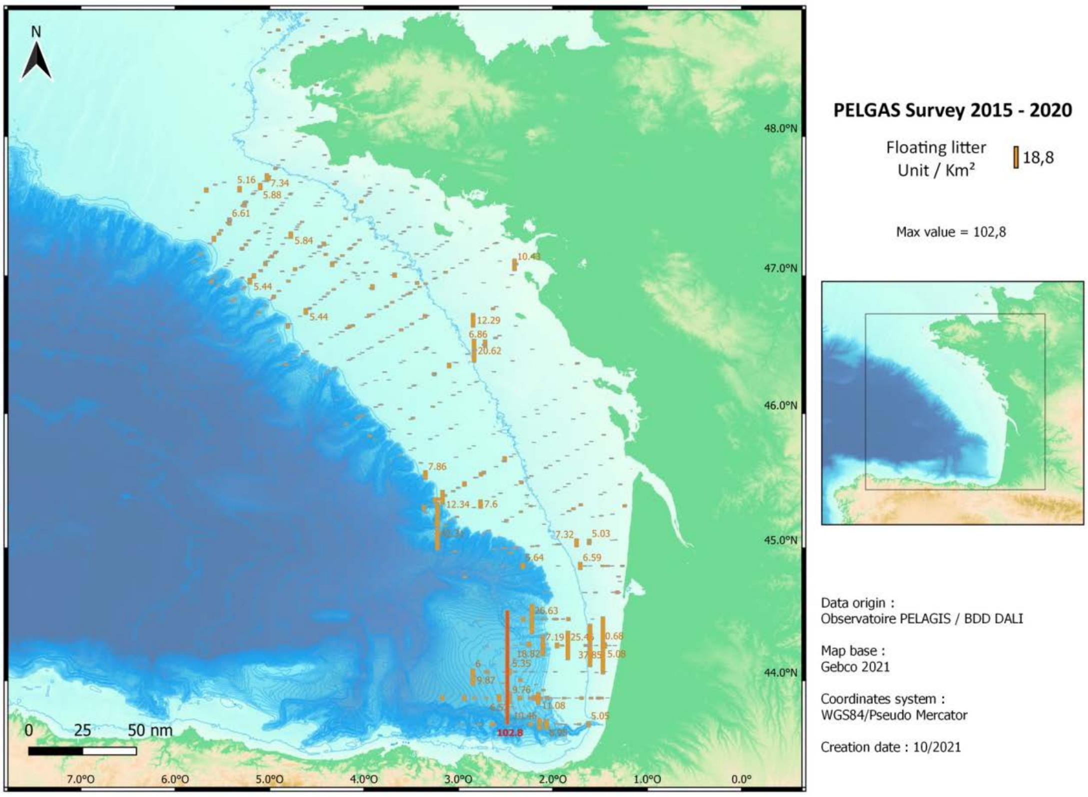


Figure 13 : Litter abundance in PELGAS campaigns 2015-2020

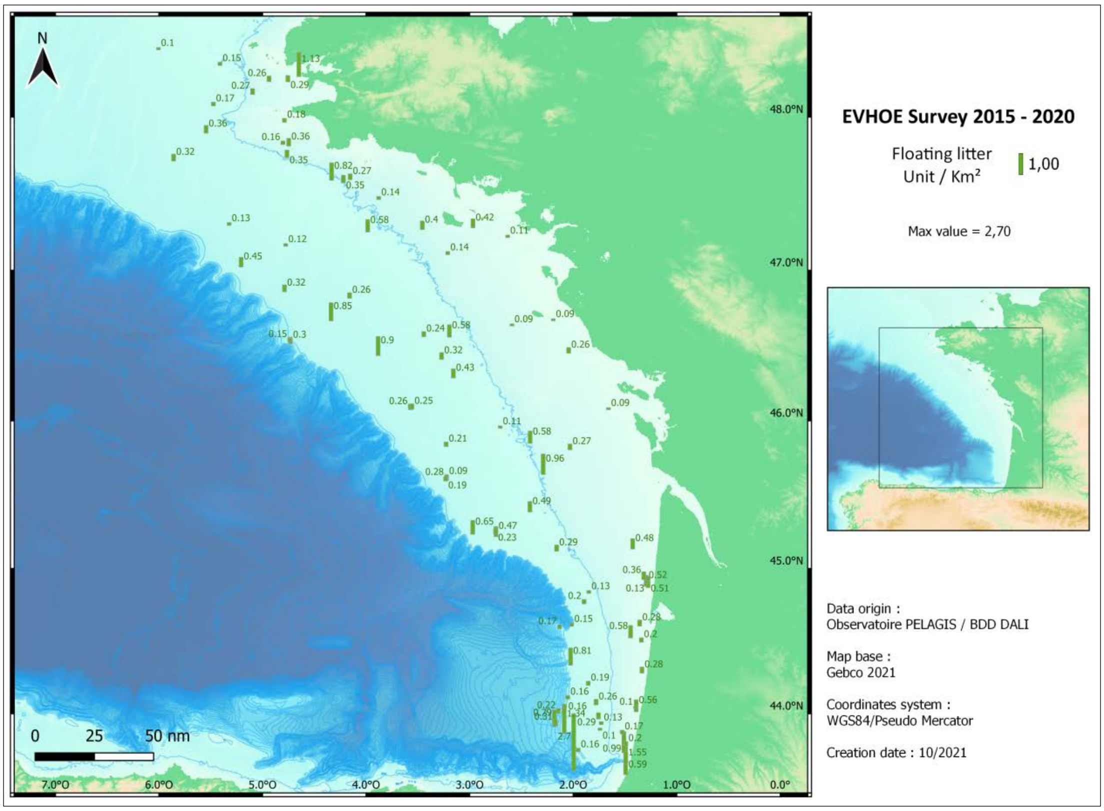


Figure 14 : Litter abundance in EVHOE campaigns 2015-2020

Conclusion

The application of MEGASCOPE protocol since 2015 in South of the North Sea/English Channel and the Bay of Biscay/Celtic Sea during these four multidisciplinary cruises generated a consistant dataset on floating Marine Litter on a large spatial area. More “in deep“analyses will support a better knowledge on the characterization of the differences between seasons, types, areas, and amounts of litter. Results show that the South of the Bay of Biscay presents the highest litter concentration compared to the south of North Sea and English Channel. Linking the data with information on riverine inputs, shipping routes, urban sources and even sea floor litter amounts and composition will largely help to better understand the cycle of plastic at sea.

To improve the knowledge on floating litter and to rely on recommandations from the MSFD, a litter typology refering to Single Use Plastic could be added to the protocol. More information on “Unspecified Litter types” should be collected to better define the sources. With this in mind, the TG ML provided in 2021 a new list named “Joint list” for a harmonized definition of the types of marine litter (Fleet et al, 2021) making it possible to identify their source more precisely, but it will certainly take some time for it to be applied on board boats. Finally an alignment of the results with the modelling of current and lagrangian transport is expected to bring next information and enable prediction of the transport of litter. Linking the outputs from WP6 to the results from field surveys will be very usefull, and a follow up of the present work.

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