Application of OSPAR Litter Assessment Guidelines to U.S. Southeast Atlantic Coast Beaches: Enhancing Comparability to French Datasets

Final Report

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Project Summary

During the ongoing COVID-19 pandemic, the daily use of personal protective equipment (PPE) and single use plastics has increased and may contribute significantly to our global plastic pollution problem. In the United States, preliminary research assessing volunteer litter cleanups suggests that plastic litter has increased in abundance and prevalence since the onset of the pandemic in both rural and coastal areas. However, without standardized methodology and sampling effort, it is difficult to track litter trends and compare pollution across regions. This project utilized standard beach litter monitoring protocols established by OSPAR, a commission of 15 countries and the European Union (EU), whose goal is to protect the marine environment of the North-East Atlantic. By applying OSPAR monitoring methods to both popular and remote beaches (n=8) along the U.S. Southeast Atlantic coast (NC, SC, GA, FL) in both the fall and winter of 2021, we were able to compare litter abundance and composition between this region and the French Atlantic coast (n=44 beaches). Along the U.S. Southeast Atlantic coast, the average number of litter items per survey was 13.9 (±13.7) per 100 m. The median number of items per survey was 8.5 per 100 m. Overall, there were no site or seasonal differences in beach litter abundance. Plastic was the most abundant type of litter, representing 82% of all recorded litter items. No pandemic-related PPE items were found on any beach during these surveys.

When compared to beach litter along the French Atlantic coast (average= 498.8 items (±646.7) per 100 m, median=286.5 items per 100 m), the beaches along U.S. Southeast Atlantic coast had significantly less litter. Plastic was also the most common litter material on French Atlantic coast, representing 90% of all recorded litter items. However, the proportions of litter among different plastic categories varied between these regions. Along the French Atlantic coast, proportions of single-use plastics were lower (21% vs. 40% in U.S.), proportions of maritime-related plastics were higher (34% vs. 11% in U.S.), and proportions of plastic fragments were similar (22% vs. 27% in U.S.). The top 10 litter items for both countries were generally similar and included plastic fragments, polystyrene fragments, plastic drink containers, cigar-and cigarette stubs, string and cord, and bottle caps, suggesting that the most important sources of marine litter are similar across the North Atlantic. Although PPE items were found on French Atlantic coast beaches during fall and winter sampling, these items were not common and represented only 0.08% of the total litter on these beaches. These findings suggest that much of the widespread pandemic-related PPE litter documented in inland and coastal regions have yet to be transported to the ocean. Differences in beach litter abundance and composition between the U.S Southeast Atlantic and the French Atlantic coasts are probably related to several factors, including single-use plastic waste generation and legislation; fisheries; and large-scale oceanic circulation patterns. Future research efforts should be directed at more broadly surveying beaches throughout the United States using these standard OSPAR guidelines to further delineate trends and possible sources of marine litter to help inform the development of effective policies and mitigation strategies for the prevention of marine litter.

Background and Aims

The coronavirus pandemic has affected the global community in profound ways, including a marked increase in the use of plastic personal protective equipment (PPE), such as disposable facemasks and gloves. While necessary to prevent viral spread and ensure public health, these PPE items are likely to contribute to our plastic litter problem if they are mismanaged or improperly disposed. In addition to PPE items, single-use plastics, such as online-shopping packages, food packaging, drink containers, and shopping bags, have been used throughout the pandemic to ensure sanitation (Prata et al., 2020). Ocean plastic models suggest that 13.6 thousand tons of mismanaged pandemic-associated waste has entered our global ocean as of August 2021 (Peng et al., 2021). Plastic litter in the marine environment is a problem of growing global concern, especially during the ongoing COVID-19 pandemic, which necessitated the increased use of single-use plastics for personal protection.

Countries, such as France, that have beach litter monitoring programs are able to methodically track patterns in plastic litter abundance and composition. Since 2010, member countries of the OSPAR Commission have regularly conducted litter surveys on over 200 beaches in the North-East Atlantic according to standardized protocols (OSPAR Commission, 2020; OSPAR Beach Litter Database). The OSPAR Coordinated Environmental Monitoring Programme (CEMP) provides guidelines for monitoring and assessing beach litter. Similar guidelines are also applied at the European Union level (European Commission, 2022). Collected data are used to track litter abundance and composition in relation to the EU threshold value of 20 items/100 m coastline (Van Loon et al., 2020), and to assess spatiotemporal patterns in litter deposition on the European coastline in the context of the Marine Strategy Framework Directive (EU Directive 2008/56/EC). Although developed for beaches along the North-East Atlantic, OSPAR monitoring guidelines have the potential to be used more broadly in coastal regions as indicated by their recent application to beach litter monitoring in tropical regions including the Caribbean (Caporusso and Hougee, 2019), Oman (van Hoytema et al. 2020), and the Solomon Islands and Vanuatu (Binetti et al., 2020). Since there are no long-term standardized data collection efforts for beach litter in the Southeastern U.S., it is challenging to confidently track patterns in abundance and composition, identify sources, or make comparisons to litter found on beaches elsewhere. The application of a standardized monitoring protocol for surveying beach litter, such as those described by the OSPAR guidelines, can be an effective way to gather data at the local and regional level to help inform the development of effective policies and mitigation strategies for the prevention of marine litter.

The aims of this study were two-fold: (1) conduct surveys of eight beaches along the U.S. Southeast Atlantic coast following OSPAR guidelines for beach litter monitoring during the fall and winter of 2021, and (2) compare the abundance and composition of litter collected on these beaches to that collected on beaches along the Atlantic coast of France during the same period.

Methods

Litter surveys were conducted in both the fall and winter of 2021 on eight beaches along the U.S. Southeast Atlantic coast: Bald Head Island, NC; Bird Island, NC; South Island, SC; Edisto Island, SC; St. Simons Island, GA; Jekyll Island, GA; Amelia Island, FL; Palm Coast, FL (Table 1, Fig. 1). The criteria used to select these beaches closely followed OSPAR guidelines for monitoring beach litter (OSPAR Commission, 2020). Specifically, all eight beaches met the following criteria:

- composed of sand, gravel, or pebbles and exposed to open sea;
- accessible to surveyors all year round;
- at least 100 m in length; and

- free of buildings all year round.

According to OSPAR guidelines, beaches preferably should not be subject to other litter collection activities. Along the U.S. Southeast Atlantic coast, most accessible beaches are regularly "swept" by volunteer organizations, especially volunteers associated with Sea Turtle Patrols during the nesting season (May-September). In this study, every effort was made to contact local authorities and volunteer organizations, including Sea Turtle Patrols, to ensure that beaches were not swept two weeks prior to our surveys. OSPAR questionnaires were completed for each beach providing a comprehensive description of each site (Table 1).

During the first survey of each beach (fall surveys), a permanent reference point was identified and used as the starting point for delineating the sampling area for both surveys. GPS coordinates of the starting point were recorded (Table 1). A 100 m long straight line was then established parallel to the back of the beach. The survey area was delineated by the two sides of the sampling unit, which were perpendicular lines on either end of the 100 m straight line, leading from the back of the beach to the waterline. The back of the beach was defined by the change in topography and presence of vegetation associated with dunes. Any litter trapped in dune vegetation was not counted as it would have been outside the survey area. All surveys occurred during a falling tide, and beach slope was measured using the Emery Method (Emery, 1961).

Within a survey area, all visible litter items were removed by having two surveyors walk side-by-side in a serpentine pattern from the dune line to the waterline. Litter items were recorded on the OSPAR survey data form, which lists 126 litter items grouped into 10 material categories (plastic, rubber, cloth or textiles, paper or cardboard, wood, metal, glass or ceramics and other) (Appendix 1). PPE gloves and masks were included as items beginning in June 2020 as a response to the COVID-19 pandemic. The presence of litter items <2.5cm, including small plastic fragments and industrial pellets, was noted but not reported in total litter abundance according to OSPAR guidelines.

Differences in litter abundance among the eight U.S. Southeast Atlantic beaches was tested using a non-parametric Kruskal Wallace rank sum test. Seasonal difference in litter abundance between the fall and winter sampling for these beaches was tested using non-parametric Wilcoxon signed-rank test for dependent samples. Litter abundance between U.S. Southeast Atlantic coast (n=8) and French Atlantic coast beaches (n=44; Fig. 1) was compared using a Mann Whitney U test for independent samples. Descriptive statistics were utilized to determine differences in litter composition and distribution. Statistics were conducted in RStudio (v. 1.4.1103) and maps were made using ArcMap (v. 10.5.1).

Results

Beach litter abundance and composition along the U.S. Southeast Atlantic coast

Along the U.S. Southeast Atlantic coast, 443 litter items were recorded and removed during 16 surveys. The average number of items per survey (±standard deviation) was 13.9 (±13.7). The median number of items per survey was 8.5. The high variance is indicative that beach litter abundance varied substantially in time and space. Edisto Island, SC had the least litter (6 items, both fall and winter), and Amelia Island, FL had the most litter (58 items, winter) (Fig. 2). There were no differences in litter abundance among the eight sampled beaches (Kruskal Wallace rank sum test, p=0.132). There were also no seasonal differences in litter abundance between the fall and winter surveys (Wilcoxon signed-rank test, p=0.672).

Plastic was the most abundant of the 10 pre-defined material groups (82% of all recorded litter items), and the predominant material at all surveyed U.S. Southeast Atlantic coast beaches (Fig. 2). Of all the plastic litter recorded across all sites, 40% was single-use, 11% was maritime-related, and 27% was fragments (Fig. 3). The highest proportion of single-use plastics was found on Bald Head Island (63%) and the lowest proportion found on Amelia Island (23%). For maritime-related plastics, the highest proportion was found on Edisto Island (33%) and the lowest proportion was found on Bird Island and South Island (5%). For plastic fragments, the highest proportion was found on Amelia Island (54%) and the lowest proportion was found on Edisto Island (0%). The top 3 litter items found on these beaches were plastic fragments (17%), cigar and cigarette stubs (15%), and polystyrene fragments (9%) (Table 2). No pandemic-related PPE items were found on any beach during these surveys, either within the designated litter survey areas or walking along the beach to and from the nearest public access points.

Comparison of plastic litter abundance and composition between beaches along the U.S. Southeast Atlantic coast and French Atlantic coast

The beaches along U.S. Southeast Atlantic coast had significantly less litter (average=13.9 items (±13.7); median=8.5 items) during fall and winter 2021 compared to beaches along French Atlantic coast (average= 498.8 items (±646.7); median=286.5 items) (Mann Whitney U test, $p=0.00000972$; Fig. 4). Similar to the beaches along the U.S. Southeast Atlantic coast, plastic was the most common litter material on French Atlantic coast beaches (82% vs. 90%, respectively) (Fig. 5). However, the proportions of litter among different plastic categories varied between these two coastlines. Along the French Atlantic coast, proportions of single-use plastics were lower (21% vs. 40% in U.S.), proportions of maritime-related plastics were higher (34% vs. 11% in U.S.), and proportions of plastic fragments were similar (22% vs. 27% in U.S.) (Fig. 5). The top 10 litter items for both countries are reported in Table 2. Plastic fragments, polystyrene fragments, plastic drink containers, cigar-and cigarette stubs, string and cord, and bottle caps were among the top litter items in both countries (Table 2). Although PPE items were found on French Atlantic beaches during fall and winter surveys (62 facemasks were reported), these items were not common and represented only 0.08% of the total litter on these beaches.

Discussion

Pandemic-related PPE as a component of beach litter

During the fall and winter sampling of 2021, we did not find any pandemic-related PPE items during our 16 surveys along the U.S. Southeast Atlantic coast, suggesting that this is not currently a common litter item on beaches in this geographic region. On French Atlantic coast beaches, PPE was not common either, only representing 0.08% of plastic litter. Since PPE, including facemasks, aren't typically worn outside and while visiting beaches, it not surprising that this wasn't a larger component of recently deposited, locally-derived plastic litter. However, pandemic-related PPE is an increasingly common litter item away from the beachfront. For example, a litter survey of the shoreline of Charleston Harbor, South Carolina conducted in September 2021 revealed that pandemic-related plastic PPE items represented 2.91% of all plastic litter (Weinstein laboratory, unpublished data). By contrast, in 2013, there were no PPE items collected in a similar survey of Charleston Harbor (Wertz, 2015). These observations suggest that pandemic-related PPE are an increasingly important contributor to plastic litter in protected bays and estuaries, where litter can be temporarily trapped and redistributed locally by wind and wave action. Based on modeling work presented by Peng et al. (2021), pandemic-associated waste from inland regions, including bays and estuaries, will eventually be transported to the ocean, perhaps over the next

3 to 4 years. Therefore, it is likely that PPE litter will become increasingly common on beaches throughout the North Atlantic Ocean in the near future.

Beach litter abundance along U.S. Southeast Atlantic coast

Levels of beach litter found along the U.S. Southeast Atlantic coast in this study are similar to that reported by Ribic et al. (2010), who examined the spatial and temporal drivers of beach litter along the U.S. Atlantic coast from data collected between 1997 and 2007. Ribic et al. (2010) found the average amount of indicator (litter) items (i.e. a standardized set of 26 common marine debris items categorized into land-based, general source, and ocean-based debris) on Southeast Atlantic coast beaches was 41.6 (±10.2) items per 500 m, or 8.3 items per 100 m. This is similar to the 13.9 items per 100 m found during the current study. By contrast, Ribic et al. (2010) found significantly more litter on beaches of the Mid-Atlantic coast (214.3 ± 100.6 items per 500 m, or 42.9 items per 100 m).

Regional differences in litter abundance in the Ribic et al. (2010) study were attributed to human population, land use, fishing activity, and oceanic currents. Low levels of land-based and general source litter, and a declining commercial fishery, were the primary drivers of low regional beach litter along the Southeast Atlantic coast, whereas increasing coastal populations, heavy land-based and general source litter, and a steady commercial fishery, were the primary drivers of higher regional beach litter along the Mid-Atlantic coast (Ribic et al., 2010). Levels of ocean-based beach litter were attributed to different factors in these two regions. Along the Southeast Atlantic coast, the Gulf Stream entrains debris and transports it away from its original source toward the northeast. As a result, beach sites nearest the Gulf Stream generally had more ocean-based litter than those beach sites further away (Ribic et al., 2020). Along the Mid-Atlantic coast, distance to the nearest port was the primary driver of ocean-based beach litter. In the current study, it is worth noting that the beaches in Florida, which were nearer to the Gulf Stream than the other sampling locations, tended to have higher abundances of beach litter.

Seasonal patterns in beach litter abundance

There was no seasonal variation in beach litter abundance at the eight sites surveyed along the U.S. Southeast Atlantic coast. The relatively higher abundance of litter items at Amelia Island, FL during winter sampling was likely due to an ongoing beach renourishment project, which could have transported litter trapped in offshore sediment back onto the beach. During fall sampling at Amelia Island, there was a large sand pipe distributing offshore sediment along the beach; this renourishment project was completed by the time we returned for winter sampling. At the other seven beach sites, similar abundances of litter were reported for both fall and winter.

Comparison of plastic litter abundance and composition between beaches along the U.S. Southeast Atlantic coast and French Atlantic coast

This study highlights the utility of a standardized monitoring protocol for surveying beach litter as an effective way to gather data to allow for direct comparisons between regions. The results of this study demonstrate apparent differences in beach litter abundance and composition between the U.S. Southeast Atlantic and French Atlantic coastlines. These differences could be driven by a variety of factors, such as patterns of plastic use, waste management, and legislation; fisheries; and large-scale oceanic circulation systems distributing ocean-based plastic litter in the North Atlantic Ocean.

The proportion of single-use plastics contributing to beach litter was twice as high along the U.S. Southeast Atlantic coast compared to the French Atlantic coast. This may be related to differences in single-use plastic waste generation and national policy between these two countries. The amount of the single-use plastic waste generated per person in the United States (53 kg per year) is considerable higher than that of France (36 kg per year) (Minderoo Foundation, 2021). Furthermore, the European Union launched in 2019 a new directive to reduce the presence of single use plastics in the environment (EU Directive 2019/904) and the French government began in 2021 to enact a series of steps to completely eliminate single-use plastics by 2040. A ban on plastic straws, cutlery, and Styrofoam take-out containers was initiated in 2021. Starting in 2022, plastic packaging for some fruits and vegetables was banned, with a complete phase-out of plastic packaging on these items by 2026. In 2023, fast food restaurants will no longer be allowed to provide disposable plates or cups. By contrast, no such policy or legislation exists at the national level in the United States. Regulations on single-use plastics, when they do exist, occur at the local or state level. For example, single-use plastic bags have been banned in California, Connecticut, Delaware, Hawaii, Maine, New York, Oregon, and Vermont.

The proportion of maritime-related plastics was 3-fold higher along the French Atlantic coast compared to the U.S. Southeast Atlantic coast. Fishing gear from the U.S. and Canada are common beach litter items along the French Atlantic coast. Plastic mesh oyster nets, presumably from more local sources, are also common beach litter items. These nets are used in oyster farming, which is a common practice along the European Atlantic coast, including the French coast (Barillé et al., 2020). In fact, oyster farms now occupy large expanses of intertidal areas along the European Atlantic coast (Barillé et al., 2020). Oysters are traditionally grown intertidally in plastic mesh nets set on a 3 × 1 m metal trestles, at a height of 1 m off the bottom (Barillé et al., 2020). Shellfish aquaculture, including oyster farming, is far less common along the U.S. Southeast Atlantic coast, where extensive natural oyster reefs are common features of the intertidal estuarine habitat. Harvesting oysters from reefs for commercial and recreational purposes is actively managed by state agencies.

Large-scale oceanic circulation systems have previously been used to explain the distribution of marine debris in Australia (Edyvane et al., 2004), the Southern Hemisphere (Gregory and Ryan, 1997), and the French Frigate Shoals in the Pacific Ocean (Morishige et al., 2007), and they may play a role in the differences in overall litter abundances between the U.S. Southeast Atlantic coast and the French Atlantic coast. In the North Atlantic Ocean, observations of beached polypropylene inkjet cartridges from a ship container spill in January 2014 reflected the principal surface currents of the region with some cartridges carried by the Azores and Canary currents around the North Atlantic Gyre, and others transported to the European coast by the North Atlantic, Portugal, and Norwegian currents (Turner et al., 2021) (Fig. 6). These observations suggest that one possible origin of ocean-based plastic litter along the French Atlantic coast is the east coast of North America. Supporting this notion are models generated by the online surface drift tool, PlasticAdrift (plasticadrift.org), which is based on drogued and undrogued drifter trajectories aggregated in the NOAA Global Drifting Buoy Program (van Sebille et al., 2014). Using these models, a piece of ocean-based plastic litter landing on a beach along the French Atlantic coast most likely would have originated from the U.S. Northeast and Mid-Atlantic coast, assuming it was adrift for 3 years or more (van Sebille et al., 2014) (Fig. 7). For a piece of ocean-based plastic litter landing on a beach along the U.S. Southeast Atlantic coast, the item most likely would have originated from the equatorial Atlantic Ocean and the west coast of Africa (Gulf of Guinea) assuming it was adrift for 3 years or more (van Sebille et al., 2014) (Fig. 8). In both cases, these models suggest that ocean-based litter adrift in the ocean for one year or less are likely to have originated from more local locations (Fig. 8).

More recent modeling incorporating not only data from the NOAA Global Drifter Buoy Program, but also ocean currents, waves at the ocean surface (e.g. Stokes drift), and wind have been used to characterize the potential sources of surface and submerged plastic litter reaching the Macaronesia archipelagos (Azores, Madeira, Canary Islands, and Cabo Verde) located in the northeast Atlantic Ocean (Cardoso and Caldeira, 2021). These models suggest that the east coast of North America is the primary source of land-based surface litter to the Azores (69.4%), Madeira (73.7%), Canaries (56.6%), and a secondary source of land-based litter to Cabo Verde (27.7%), which is closer to the African coast. Given that the U.S. has the highest annualized per capita plastic waste generation rate (~122 kg/person/year) and a large coastal population (112.9 million people) resulting in an estimated plastic marine debris production of 0.04-0.11 million tons/year (Jambeck et al. 2015), Cardoso and Caldeira (2021) conclude that the east coast of the U.S. is the most probable source of plastic litter in this region.

Conclusions

Beach litter is often a mixture of items from land-based sources, such as urban areas, harbors, tourism, and recreation, and ocean-based sources, such as shipping, fisheries and aquaculture (OSPAR Commission, 2020). These sources can be local, regional, or distant, as litter may be transported by ocean currents, rivers, and wind. Thus, identifying exact sources and points of origin for any given litter item is nearly impossible. However, the use of standardized sampling protocols, such as that developed by OSPAR, can be used across locations and regions to identify broad trends in various types of marine litter, which in turn can be used to infer possible sources. Our findings suggest that regional differences in plastic litter abundance and composition between the U.S. Southeast Atlantic coast and French Atlantic coast may be the result of single-use plastic waste generation and legislation; fisheries; and large-scale oceanic circulation patterns. Future research efforts should be directed at more broadly surveying beaches throughout the United States using these standard OSPAR guidelines to further delineate trends and possible sources of marine litter to help inform the development of effective policies and mitigation strategies for the prevention of marine litter.

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Tables

Table 1. Sampling site characteristics for U.S. Southeast Atlantic coast beach sites.

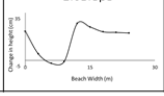
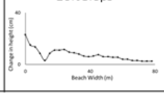
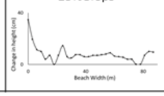
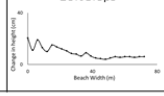
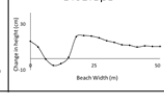
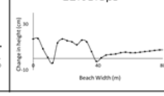
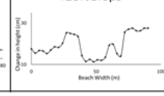
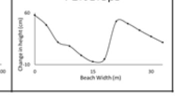
	NC	NC	SC	SC	GA	GA	FL	FL
	9-Sep	**8-Sep**	**25-Aug**	**9-Aug**	**28-Sep**	**28-Sep**	**27-Sep**	**27-Sep**
	7	**9**	**10**	**6**	**14**	**7**	**7**	**23**
	9	13	1	3	38	6	11	157
	1	35	7	28	6	6	6	19
	9.7 m/s SSW	5.2 m/s SSE	3.6 m/s S	2.3 m/s ESE	2.2 m/s SE	1.5 m/s ENE	2.5 m/s E	ENE, 1.8 m/s
)	**8-Dec**	**7-Dec**	**2-Dec**	**16-Dec**	**15-Dec**	**15-Dec**	**14-Dec**	**14-Dec**
	6	**10**	**12**	**6**	**8**	**8**	**58**	**32**
	2	4	1	0	1	3	170	24
	31	77	25	39	38	38	5	38
	1.1 m/s SE	8.5 m/s NE	3.1 m/s W	2.8 m/s NNE	5.2 m/s N	5.3 m/s N	3.7 m/s N	N, 5 m/s
)	Bald Head Island, NC (182)	Sunset Beach, NC (4,037)	Georgetown, SC (89,800)	Seabrook Island, SC (1,762)	St. Simons Island, GA (14,778)	Jekyll Island, GA (605)	Fernandina Beach, FL (13,052)	Palm Coast, FL (89,800)
town	within town limits	2.4 km NE	20.8 km N	3.2 km E	within town limits	within town limits	8.2 km N	1.9 km SW
year)	Cape Fear River (4,745)	Cape Fear River (4,745)	Winyah Bay (365)	Charleston Harbor (22,630)	St. Simons Sound (3,600)	St. Simons Sound (3,600)	St. John's River (13,870)	St. John's River (13,870)
ping lane	5.9 km W	48.5 km E	8.3 km NE	39.8 km NE	3.0 km SW	10.4 km N	20.2 km N	93.5 km N
	Cape Fear River	Little River	North Santee River	Edisto River	East River	East River	Nassau Sound	Mantanzas River
river	5.9 km W	1 km SW	2.9 km SW	2.3 km NE	3 km W	2.9 km SW	1.5 km S	10.2 km N
n?	no	no	no	no	houses behind dunes and maritime forest	no	houses behind dunes outside of sampling site boundaries	houses behind dunes and maritime forest
nt?	no	no	no	no	yes, 1.68 km SW	yes, 1.62 km N	yes, 2.9 km to N	yes, 1.6 km S
	33.855381, -77.960064	33.853997, -78.537328	33.150825, -79.222308	32.547242, -80.227064	31.148747, -81.365572	31.030597, -81.415358	30.529736, -81.437117	29.619911, -81.191864
	Bald Head Island Conservancy, Village of Bald Head Island	NC Coastal Reserve and National Estuarine Research Reserve	Tom Yawkey Wildlife Center, SC Department of Natural Resources	Botany Bay Plantation Wildlife Management Area, SC Department of Natural Resources	Glynn County Massengale Park	Jekyll Island Authority	Nassau County Amelia Island Public Access	Flagler County MalaCompra Beach Park
	seasonal tourism	seasonal tourism, local recreation	research only; closed to public	seasonal tourism, local recreation	seasonal tourism, local recreation	seasonal tourism, local recreation	year round and seasonal tourism, local recreation	year round and seasonal tourism, local recreation
	yes	yes	no, not open to public	yes	yes	yes	yes, ordinance 2016-06	yes, ordinance 23.2
n)	26.7	79.2	80.4	149	121.8	149	123.1	60
n)	1.5	9.4	9.4	80.6	68.5	80.60	96.50	35.30
)	14.35	6.21	7.03	5.43	2.62	13.87	22.42	76.21
	eroding dunes	medium dunes	small dunes	sandy washout	small dunes	large dunes	small dunes	small dunes
	E	S	SE	SE	SE	E	E	E
	100% sand	100% sand	100% sand	60% sand, 40% shell	100% sand	100% sand	70% sand, 30% shell	80% sand, 20% pebbles
	<1% slope	26% slope	29% slope	20% slope	9% slope	12% slope	+23% slope	71% slope
								

Table 2. Ten most common litter items found on U.S. Southeast Atlantic coast and French Atlantic coast beaches in fall and winter 2021. *indicates litter items common in both countries.

Top U.S. Southeast Atlantic Beach Litter		
Ranking	**Litter Type (OSPAR ID)**	
1	Plastic Fragments >2.5cm (461)*	17%
2	Cigar and Cigarette Stubs (64)*	15%
3	Styrofoam Fragments >2.5cm (462)	9%
4	Bottle Caps (15)*	7%
5	String and Cord (321)*	7%
6	Plastic Cutlery (22)	5%
7	Balloons (49)	4%
8	Plastic Bags (3)	3%
9	Plastic Drink Containers (4)*	3%
10	Metal Fragments >2.5cm (89)	3%
Top French Atlantic Beach Litter		
Ranking	**Litter Type (OSPAR ID)**	
1	Plastic Fragments >2.5cm (461)*	15%
2	String and Cord (321)*	12%
3	Plastic Oyster Nets (28)	8%
4	Sytrofoam Fragments >2.5 (462)	7%
5	Bottle Caps (15)*	7%
6	Fishing Net Fragment >2.5cm (115)	7%
7	Plastic Crisp Packets (19)	4%
8	Other Plastic (48)	4%
9	Plastic Drink Containers (4)*	3%
10	Cigar and Cigarette Stubs (64)*	3%

Figures

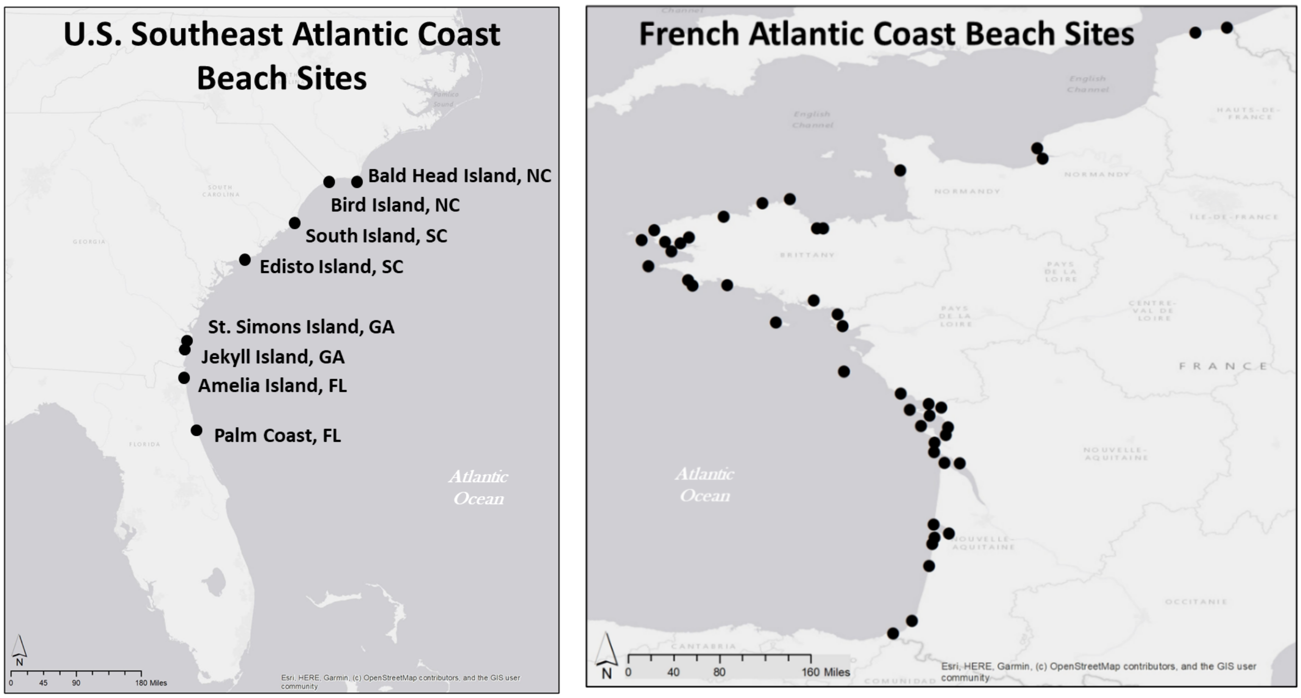


Figure 1. Map of the U.S. Southeast Atlantic coast and French Atlantic coast sampling sites with black dots indicating those beach sites surveyed.

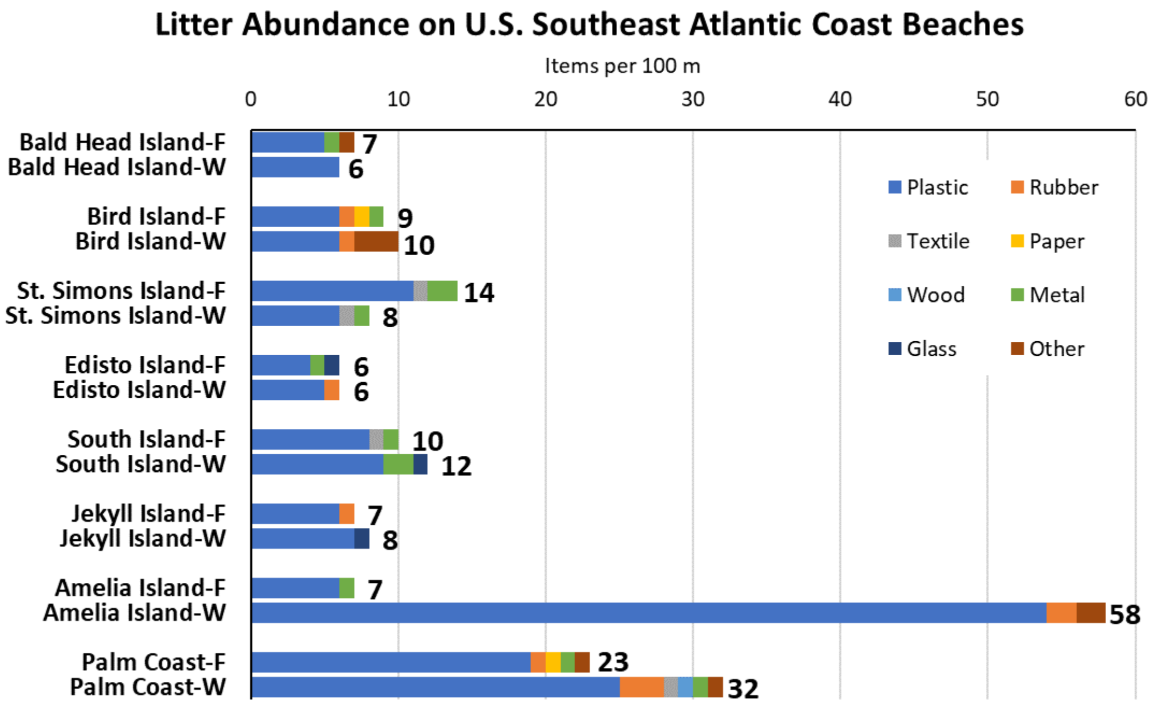
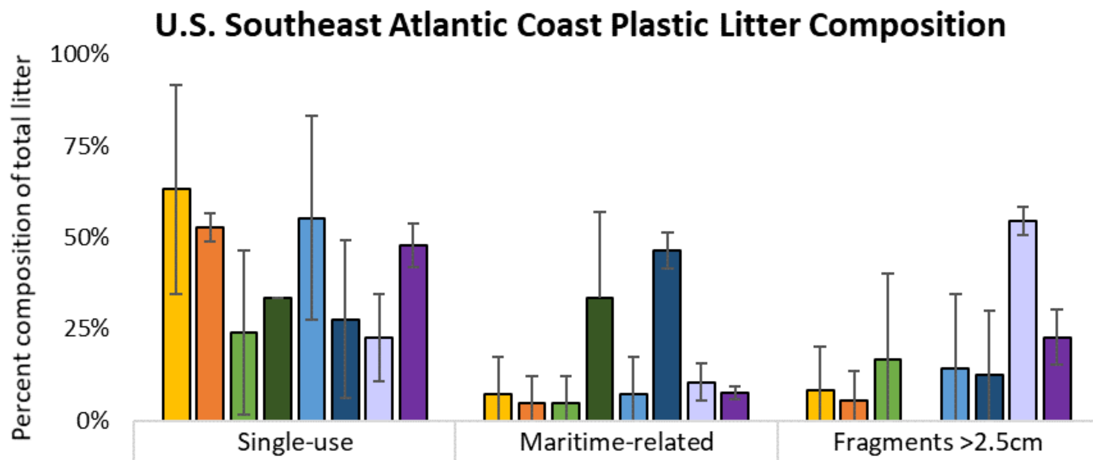


Figure 2. Total litter abundance on U.S. Southeast Atlantic coast beaches during fall (F) and winter (W) sampling in 2021 broken down by material types.



	Single-use	Maritime-related	Fragments >2.5cm
Bald Head Island	63%	7%	8%
Bird Island	53%	5%	6%
South Island	24%	5%	17%
Edisto Island	33%	33%	0%
St. Simons Island	55%	7%	14%
Jekyll Island	28%	46%	13%
Amelia Island	23%	11%	54%
Palm Coast	48%	7%	23%

Figure 3. Mean percent composition of single-use plastics, maritime-related plastics, and plastic fragments >2.5cm for each U.S. Southeast Atlantic coast site sampled in this survey.

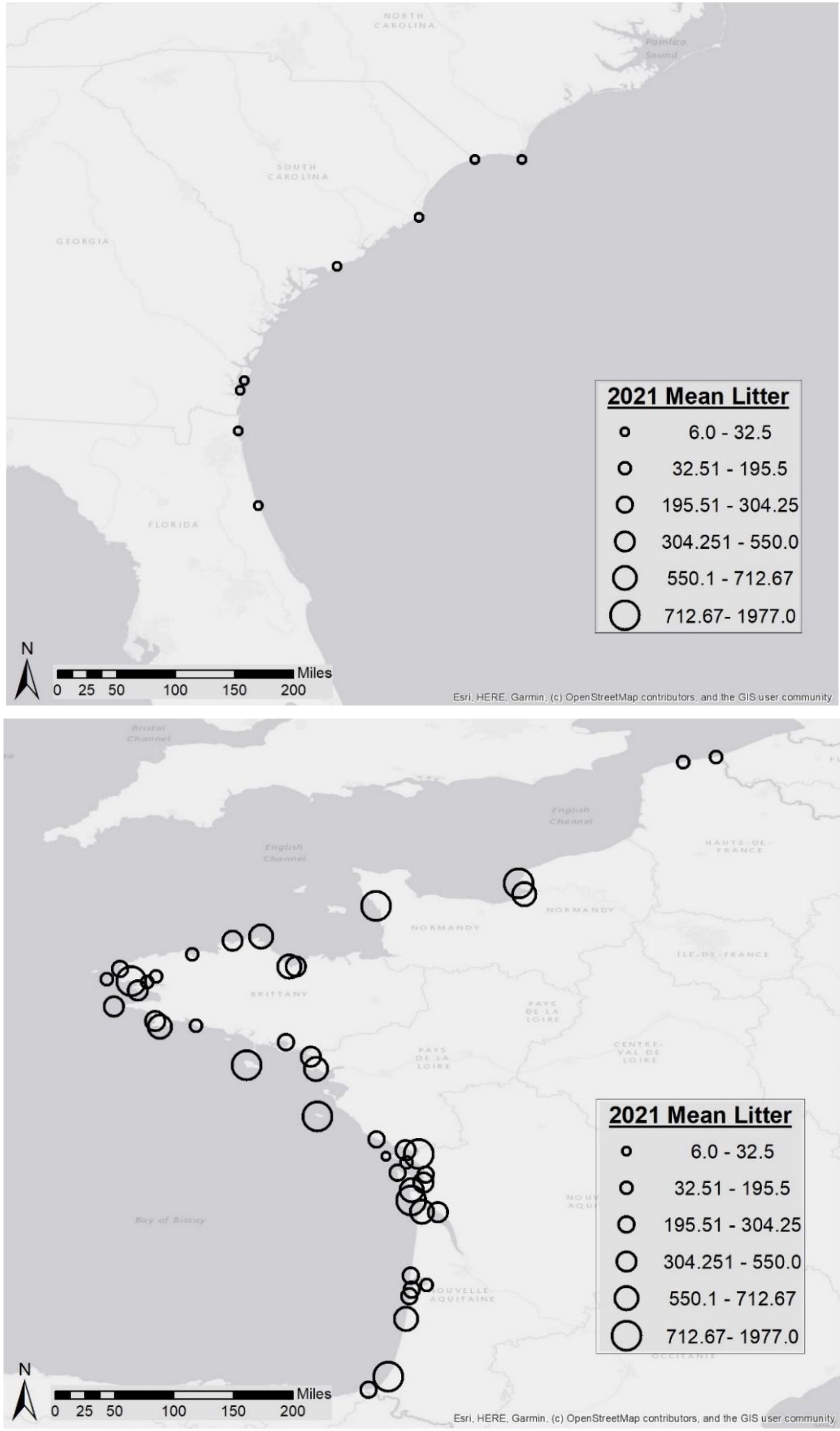


Figure 4. Mean litter abundance found using OSPAR sampling protocols along the U.S. Southeast Atlantic coast (top) and French Atlantic coast (bottom) in fall and winter 2021 with circle size indicating mean abundance of litter items.

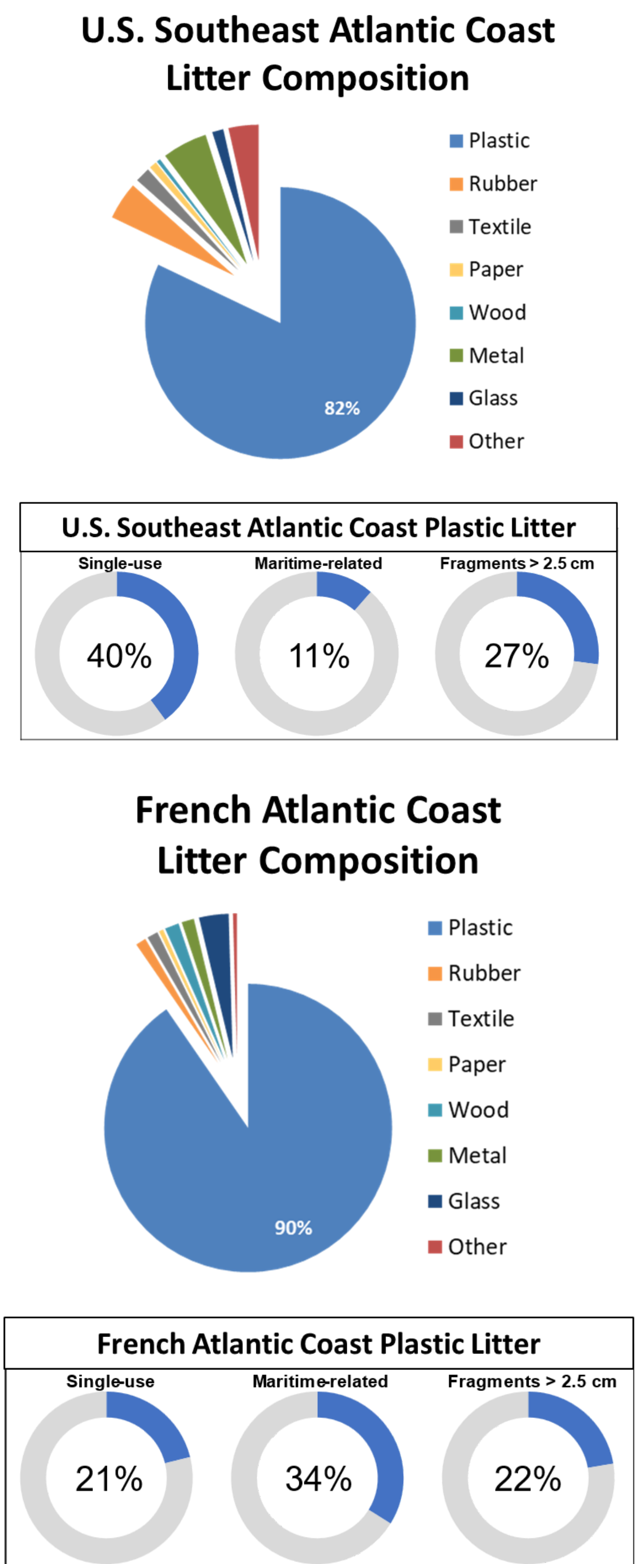


Figure 5. Types of litter found on beaches along the U.S. Southeast Atlantic coast (top) and French Atlantic coast (bottom) by material types and a breakdown of the three major types of plastic litter found in these regions in fall and winter 2021.

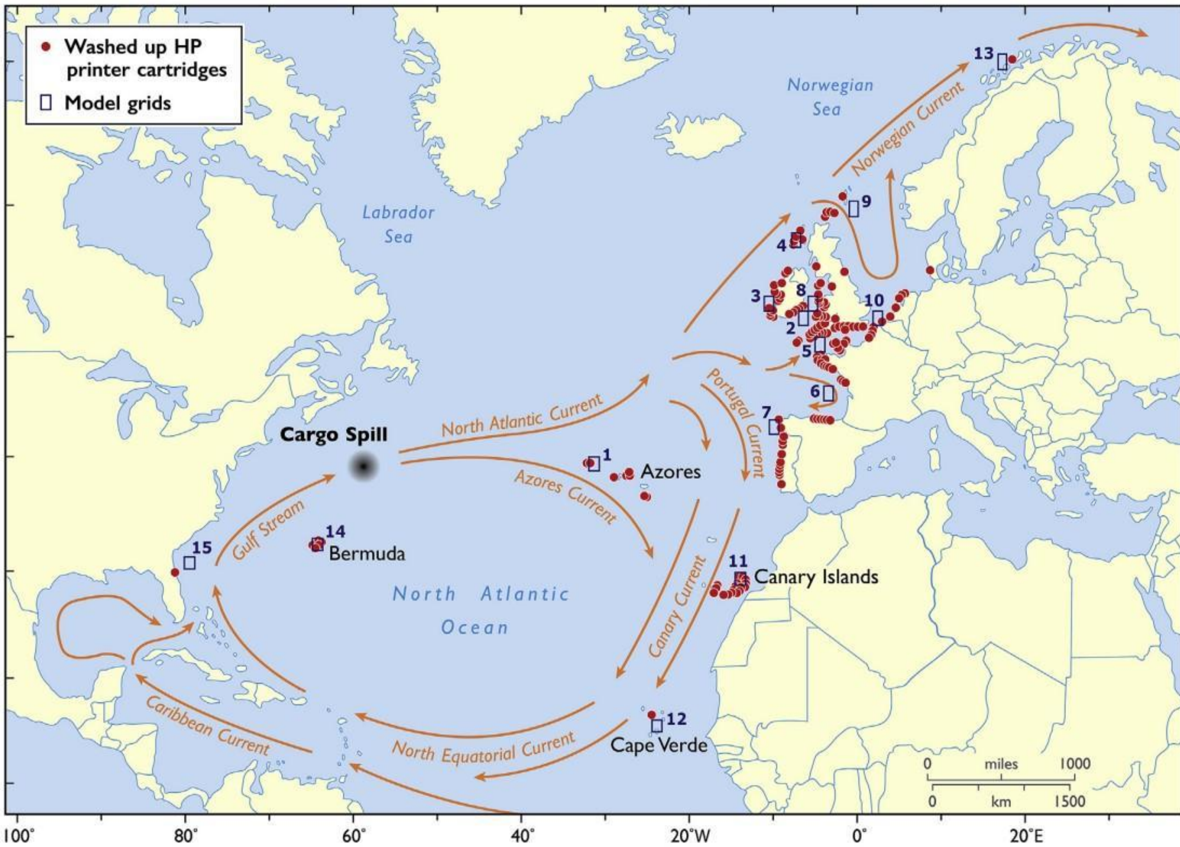


Figure 6. Sightings of washed-up inkjet cartridges (red dots) in 2014 to 2017 relative to surface currents in the North Atlantic Ocean. The release of inkjet cartridges was the result of a spill on the cargo ship "Suez Canal Bridge" on 23 January 2014. Figure from Turner et al. (2021).

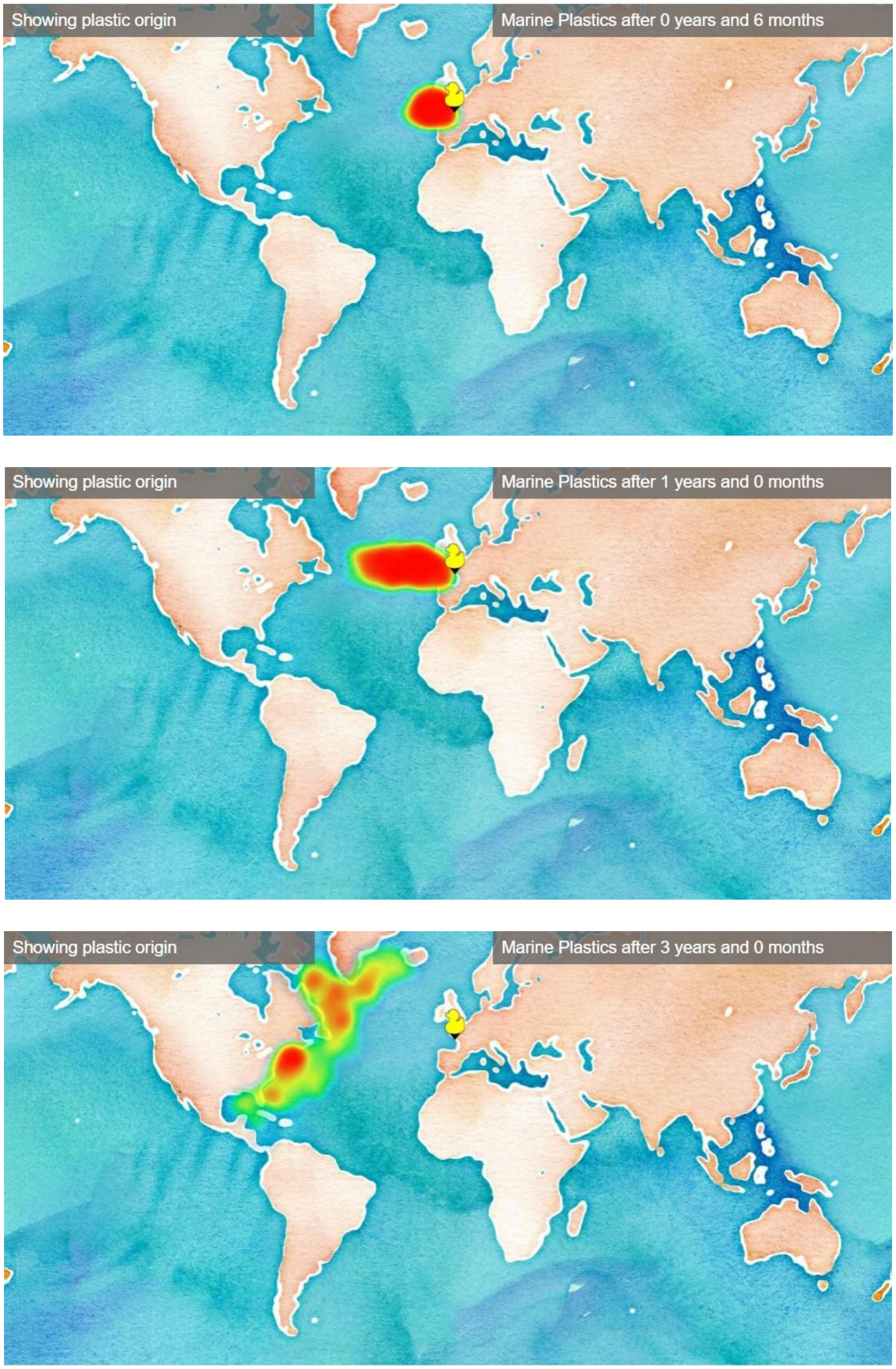
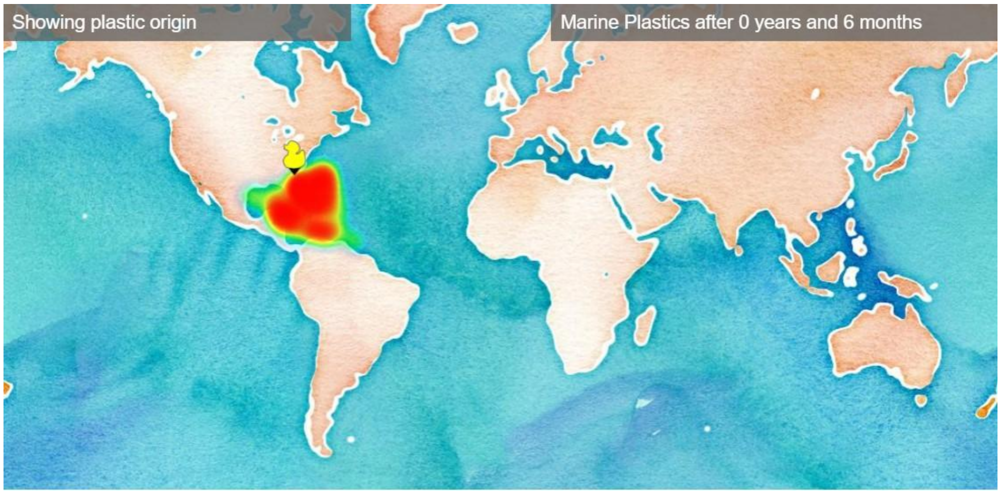
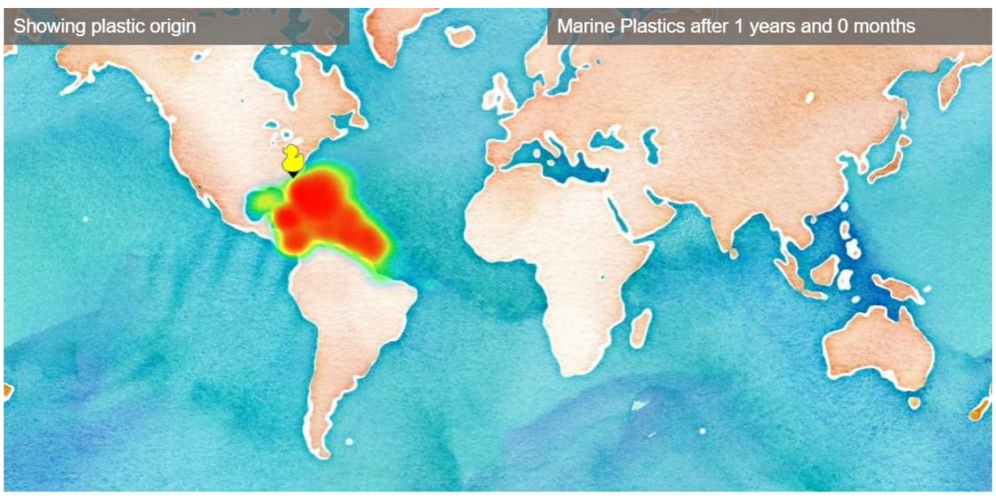


Figure 7. Models examining origin of ocean-based plastic litter for French Atlantic coast beaches. Model runs assume plastic entered marine environment 6 months ago, 1 year ago, and 3 years ago. Bath toy symbol represents location of hypothetical beached litter. Red areas indicated highest probability where

plastic litter originated. Maps generated at PlasticAdrift.org based on models developed by van Sebille et al. (2014).





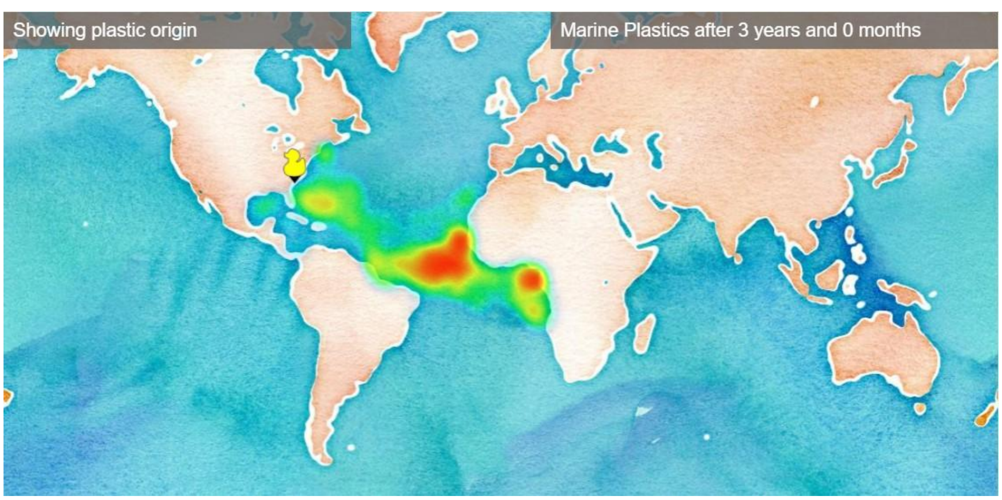


Figure 8. Models examining origin of ocean-based plastic litter for U.S. Southeast Atlantic coast beaches. Model runs assume plastic entered marine environment 6 months ago, 1 year ago, and 3 years ago. Bath toy symbol represents location of hypothetical beached litter. Red areas indicated highest probability where plastic litter originated. Maps generated at PlasticAdrift.org based on models developed by van Sebille et al. (2014).

Appendix. Litter items recorded in this study sorted by material type, adapted from OSPAR protocols (OSPAR Commission, 2020).

OSPAR ID	Litter type	Included in Total Count	Single-use plastics (SUP)	Maritime-related plastic items
ARTIFICIAL POLYMER MATERIAL (PLASTIC)				
1	4/6-pack yokes	x		
2	Bags	x	x	
3	Small plastic bags	x		
112	Plastic bag ends	x		
4	Drinks (bottles, containers and drums)	x	x	
5	Cleaner (bottles, containers and drums)	x		
610	Food containers incl. fast food containers (plastic)	x	x	
620	Food containers incl. fast food containers (polystyrene)	x	x	
7	Cosmetics (bottles & containers)	x		
8	Engine oil containers and drums < 50 cm	x		
9	Engine oil containers and drums > 50 cm	x		
10	Jerry cans	x		
11	Injection gun containers	x		
12	Other bottles, containers and drums	x		
13	Crates	x		
14	Car parts	x		
15	Caps/lids	x	x	
16	Cigarette lighters	x		
17	Pens	x		
18	Combs/hair brushes	x		
19	Crisp/sweet packets and lolly sticks	x	x	
20	Toys & party poppers	x		

211	Cups (plastic)	x	x	
212	Cups (polystyrene)	x	x	
22	Cutlery/trays/straws	x	x	
23	Fertiliser/animal feed bags	x		
24	Mesh vegetable bags	x		
25	Gloves (typical washing up gloves)	x		
113	Gloves (industrial/professional gloves)	x		
26	Crab/lobster pots	x		x
114	Lobster and fish tags	x		x
27	Octopus pots	x		x
28	Oyster nets or mussel bags incl. plastic stoppers	x		x
29	Oyster trays	x		x
30	Plastic sheeting from mussel culture	x		x
31	Rope (diameter more than 1 cm)	x		x
322	String and cord (diameter less than 1 cm) – dolly ropes	x		x
321	String and cord (diameter less than 1 cm) – others	x		x
115	Nets and pieces of net < 50 cm	x		x
116	Nets and pieces of net > 50 cm	x		x
331	Tangled nets/cord/rope and string	x		x
332	Tangled dolly ropes	x		x
341	Fish boxes (plastic)	x		
342	Fish boxes (polystyrene)	x		
35	Fishing line (angling)	x		x
36	Light sticks (tubes with fluid)	x		x
37	Float/Buoys	x		x
38	Buckets	x		
39	Strapping bands	x		
40	Industrial packaging, plastic sheeting	x		

41	Fibre glass	x		
42	Hard hats	x		
43	Shtogun cartridges	x		
44	Shoes/sandals	x		
45	Foam sponge	x		
1171	Plastic/polystyrene pieces 0 - 2.5 cm (plastic)			
1172	Plastic/polystyrene pieces 0 - 2.5 cm (polystyrene)			
461	Plastic/polystyrene pieces 2.5 - 50 cm (plastic)	x		
462	Plastic/polystyrene pieces 2.5 - 50 cm (polystyrene)	x		
471	Plastic/polystyrene pieces > 50 cm (plastic)	x		
472	Plastic/polystyrene pieces > 50 cm (polystyrene)	x		
48	Other plastic/polystyrene items	x		
481	Biomedias	x		
64	Cigarette butts	x	x	
97	Condoms	x		
981	Cotton bud sticks (plastic)	x	x	
99	Sanitary towels/panty liners/backing strips	x	x	
100	Tampons and tampon applicators	x	x	
101	Toilet fresheners	x		
103	Containers/tubes	x		
104	Syringes	x		
1051	Face masks	x		
1052	Single-use gloves	x		
121	Bagged dog faeces	x		
RUBBER				
49	Balloons, incl. plastic valves, ribbons, strings etc.	x	x	
50	Boots	x		
52	Tyres and belts	x		

53	Other rubber pieces	x		
CLOTH				
54	Clothing	x		
55	Furnishing	x		
56	Sacking	x		
57	Shoes (leather)	x		
59	Other textiles	x		
PAPER / CARDBOARD				
60	Bags	x		
61	Cardboard	x		
118	Cartons e.g. tetrapak (milk)	x		
62	Cartons e.g. tetrapk (other)	x		
63	Cigarette packets	x		
65	Cups	x		
66	Newspapers & magazines	x		
982	Cotton bud sticks (cardboard)	x		
67	Other paper items	x		
PROCESSED / WORKED WOOD				
68	Corks	x		
69	Pallets	x		
70	Crates	x		
71	Crab/lobster pots	x		
119	Fish boxes	x		
72	Ice lolly sticks/chip forks	x		
73	Paint brushes	x		
74	Other wood < 50 cm	x		
75	Other wood > 50 cm	x		
METAL				

76	Aerosol/Spray cans	x		
77	Bottle caps	x		
78	Drink cans	x		
120	Disposable BBQ's	x		
79	Electric appliances	x		
80	Fishing weights	x		
81	Foil wrappers	x		
82	Food cans	x		
83	Industrial scrap	x		
84	Oil drums	x		
86	Paint tins	x		
87	Lobster /crab pots and tops	x		
88	Wire, wire mesh, barbed wire	x		
89	Other metal pieces < 50 cm	x		
90	Other metal pieces > 50 cm	x		
GLASS AND CERAMICS				
91	Bottles	x		
92	Light bulbs/tubes	x		
93	Other glass items	x		
931	Jars	x		
94	Construction materials e.g. tiles	x		
95	Octopus pots	x		
96	Other ceramic/pottery items	x		
UNDEFINED				
102	Other sanitary items	x		
105	Other medical items (swabs, bandaging etc.)	x		
POLLUTANTS				
108	Paraffin or wax pieces (0 - 1 cm)			

109	Paraffin or wax pieces (1 - 10 cm)			
110	Paraffin or wax pieces (> 10 cm)			
111	Other pollutant			