

PROJECT FINAL REPORT

Occurrence and Distribution of Microplastics from Coastal National Park Units in the Southeastern United States

Task Agreement Number P12AC11162: Dissolved and particular anthropogenic organic pollutants in the coastal environments of the Southeastern US

Study Period: 09/01/2012 - 06/30/2015

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Citation:

Whitmire, S; Yu, X; Toline, CA; Chow, A and Ladewig, S, Bao, S. 2016. Occurrence and Distribution of Microplastics from Coastal National Park Units of the Southeastern United States. Final Report (with two supplements).

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EXECUTIVE SUMMARY

Microplastics are debris of emerging concern in marine environments; they are small enough to be ingested by marine organisms; additionally, they have relatively large surface areas which are hydrophobic and can therefore adsorb and transport a variety of toxins. To investigate the occurrence and distribution of microplastics in the southeastern coastal region of the United States, we analyzed sediment samples from multiple coastal sites and developed a predictive model to understand drift of plastics via ocean currents. Sand samples from eighteen National Park Service (NPS) sites in the Southeastern Region were collected. Microplastics were isolated using density separation and counts of microplastic particles were compared among sites. Local geography was used to make inferences about sources and modes of distribution. A subset of samples was analyzed to identify composition of particles using Fourier transform infrared spectroscopy (FTIR). To predict the spatiotemporal distribution and movements of particles in the coastal oceans, a Regional Ocean Modeling System (ROMS) model was applied.

Microplastics were detected in each of the sampled Southeastern NPS units although abundance among sites was highly variable. Approximately half of the samples were dominated by thread-like and fibrous materials as opposed to beads and particles. Within the small FTIR sampled subset, twenty-four percent consisted of polyethylene terephthalate (PET). Based on studies examining sources of microplastics, the shape of the particles found here (mostly fibers) and the presence of PET, we infer the source of microplastics in coastal areas is mainly from urban areas, such as wastewater discharge, rather than breakdown of large marine debris floating in the ocean.

Local geographic features, e.g., the nearness of sites to large rivers and urbanized areas, explains variance in amount of microplastics among sites. Additionally, distribution of simulated particles is explained by ocean current patterns; computer simulations were correlated with field observations, reinforcing that ocean currents can be a good predictor of the fate and distribution of microplastics in the sites sampled here.

1. INTRODUCTION

The total global production of plastics grew nearly 200 times in the last half century, from 1.5 million tons in 1950 to 280 million tons in 2012 (Rochman et al., 2013). Degradation processes of plastics are extremely slow; therefore, plastics can become an environmental hazard when they enter in the marine environment. Plastic entanglement and ingestion by marine birds, mammals, fish, and reptiles resulting in injury and death are frequently reported (Derraik, 2002; Gregory, 2009; Lozano and Mouat, 2009). Additionally, the presence of plastic debris in the marine environment has economic repercussions for tourist and marine industries (Barnes et al., 2009; Derraik, 2002; Sivan, 2011). Therefore, many state and federal agencies and non-government organizations have established marine debris programs to manage and research plastic debris (NOAA, 2015; USEPA, 2015).

Plastic debris found in the marine environment varies in size, from large to microscopic pieces. In recent years, there has been increasing environmental concern about ‘microplastics’. Microplastics are generally defined as plastic particles (pieces, fibers, or beads) that are less than 5 mm in size. These small plastic fragments are derived from the breakdown of large plastic debris, or as small manufactured pieces such as tiny plastic beads used as scrubbers in cosmetics, and fabric and polymeric materials from clothes (Derraik, 2002; Ryan et al., 2009; Thompson et al., 2004; Browne, 2015; Ladewig et al. 2015). Because of their small size and low density, microplastics are considered readily bioavailable to organisms throughout the food-web (Andrady, 2011; Cole et al., 2011). Additionally, the relatively hydrophobic properties and large surface area make microplastics prone to adhering persistent organic pollutants (POPs). Ingestion of microplastics may therefore be transferring these POPs to aquatic organisms (Teuten et al., 2009). Noticeably, microplastics have been reported in marine waters worldwide and accumulate in depositional environments, including sandy beaches and marine sediments in remote and protected areas (Cozar et al., 2014; Juan et al., 2014; Turra et al., 2014; Lusher, 2015).

The relatively flat southeastern US coastal plain and seashore provide a variety of coastal habitats for wildlife and are important resources for fishery and tourist industries across the region (US Fish & Wildlife Service, 2015). However, data about the occurrence and distribution of microplastics in this area are relatively limited. Many observations of large plastic debris in this area have been frequently reported (Viehman et al., 2011) and, in turn, microplastics should not be ignored. The US National Park Service (NPS) manages 69,463 km of shoreline nationally and over 8,237 km within the Southeast Region (National Park Service, 2015). Despite protection from a variety of anthropogenic activities, these sites remain prone to many of the same stressors as other coastal sites including the effects of marine debris. However, these sites also range widely in their distance from the immediate impacts of urbanized areas. These features make the NPS units ideal sites for gaining an understanding of the large scale distribution of microplastics while providing these protected areas with valuable information about potential for input of microplastics into their habitats. The two main objectives of this study are to: 1) determine if there is microplastic contamination at the coastal NPS units and what might be the relative extent, and 2) investigate the factors that influence microplastic distribution among these sites.

Sand samples were collected from eighteen coastal sites, representing sixteen NPS units along the southeastern coastline of United States, from North Carolina to Texas. Two sites in the US Virgin Islands located in the Caribbean Sea were also included in the study. The sites selected vary in broad geographical features (e.g. barrier islands, estuaries, etc.) and distance to developed areas. The effects of both these natural and anthropogenic factors are used to understand the occurrence and distribution of microplastics in this region.

2. MATERIALS AND METHODS

2.1. Field Sampling Collections

Eighteen coastal sites from sixteen National Parks Service (NPS) units in the southeastern region were selected for this study. Sixteen sites were located from North Carolina to Texas, with two sites in the US Virgin Islands (Table 1, Figure 1). Sampling locations within a park were selected by park staff based on where they had consistently observed accumulation of large marine debris. All sand samples were collected by NPS staff using sampling kits provided by the research team. The sampling kits included a written procedure with a visual illustration (**see Supplement A at end of document**), a metal sampling ring, a small metal shovel, premade aluminum foil bags, a blank data sheet, and a box with return postage. Samples were collected at low tide along a 50-meter transect between the high and low tide lines parallel with the shore close to the high tide line. To keep sample sizes consistent, the metal ring with a 25-cm diameter and 1.5-cm height (equivalent volume = 736 cm^3) was pressed into the top sand layer; material within the ring was carefully collected using the metal shovel and subsequently transferred into an aluminum foil bag. A total of 10 samples were collected from each site. The bags were carefully folded and packed, and shipped back to the laboratory at the Baruch Institute of Coastal Ecology & Forest Sciences at Georgetown SC for processing. All sand samples were collected in 2013 between July and October.

Table 1. The park unit abbreviation, NPS unit sampled, and geographical coordinates of the eighteen NPS sites sampled.

NPS Abbreviation	NPS Unit	Latitude N.	Longitude W.
CAHA	Cape Hatteras National Seashore	35°46'39.68"	75°32'05.96"
CALO	Cape Lookout National Seashore	34°40'17.60"	76°36'43.70"
FOSU	Fort Sumter National Monument	32°45'07.19"	79°52'31.00"
FOPU	Fort Pulaski National Monument	32°01'53.00"	80°53'34.80"
CUIS	Cumberland Island National Seashore	30°46'54.88"	81°27'21.91"
TIMU	Timucuan Ecological & Historical Reserve	30°34'24.50"	81°26'34.30"
FOMA	Fort Matanzas National Monument	29°42'39.31"	81°13'34.50"
CANA	Canaveral National Seashore	28°41'08.06"	80°39'15.15"
BISC	Biscayne National Park	25°28'51.18"	80°10'46.20"
EVER	Everglades National Park	25°07'20.88"	81°01'54.82"
DRTO	Dry Tortugas National Park	24°37'57.99"	82°55'17.76"
BICY	Big Cypress National Preserve	25°47'31.30"	81°25'10.00"
GUIS (PK)	Gulf Islands National Seashore - Perdido Key	30°18'34.70"	87°22'01.96"
GUIS (HI)	Gulf Islands National Seashore - Horn Island	30°13'56.31"	88°30'39.47"
GUIS (WS)	Gulf Islands National Seashore - West Ship Island	30°12'46.84"	88°58'18.91"
PAIS	Padre Island National Seashore	27°14'09.90"	97°37'31.50"
VIIS	Virgin Islands National Park	18°21'22.13"	64°44'45.37"
BUIS	Buck Island Reef National Monument	17°47'23.14"	64°37'32.34"



Figure 1. Eighteen sites sampled for microplastics at southeastern NPS units.

2.2. Microplastic Isolation and Quantification

Sand samples were dried at 50 °C for at least 48 hours upon receipt. Five dried samples from each site were randomly selected for microplastic quantification. A density separation method as described in Thompson et al (2004) and Hidalgo-Ruz et al (2012) was employed for isolating microplastics from the sand matrix. A 100 g of dried sand ($V \approx 60 \text{ cm}^3$) was mixed with a 250 mL saturated salt solution (NaCl with $\rho \approx 1.27 \text{ g/mL}$) and manually stirred with a glass rod for two minutes in a shallow aluminum plate with a diameter of 35 cm. Results of our preliminary experiments indicated that the recovery of microplastics in a wide-open plate (i.e., larger surface area) with a thinner layer of sand was significantly higher than that of regular flasks containing a thicker layer of sand with the same amount of materials. After two hours of settlement, the water solution above the sand layer was carefully transferred to a 500 mL beaker for an additional one hour of settlement. The solution was then filtered through a 47 mm glass-fiber filter with 1.0 μm pore size (GF/B, Whatman, USA). The 500 mL beaker and all the transfer apparatus were washed with deionized water multiple times and all washing solutions were filtered through the same glass-fiber filter to minimize any sample loss due to adhesion of microplastics on the wall of any of the filter apparatus. Filters were air dried for 24 hours and subsequently sealed individually in petri dishes for further quantitative and qualitative analyses. This isolation process was repeated three times for each sample to increase the recovery. A new glass fiber filter was used in the repeated isolation for a total of three filters for each sample. Our preliminary study demonstrated a single isolation recovered less than 62% (assuming 100% recovery after three repeated isolation steps) of microplastics in the sand matrix. Generally the number of isolated particles decreased exponentially with the number of repeated isolation and the third isolation usually represented less than 10% of the sum of three consecutive isolations. Based on the decreasing trend on microplastic pieces in our isolation procedures, we estimated the three repeated isolation steps should recover >90% of microplastics in the sand matrix.

To quantify the number and the size of microplastics, the filters were examined using an AM3011 digital microscope (Dino-Lite Digital Microscope, USA) at 75x magnification. The length of microplastics was measured using the software equipped with the digital microscope after calibration with a standard. The entire filter was scanned thoroughly and a detection limit down to .01 mm was achieved. Large pieces of vegetable debris such as seaweed and dry leaves were visually picked out with tweezers. A total of 270 filters were visual quantified (18 sites, five samples from each site, and three repeated isolations from each sample) using pre-set criteria (Hidalgo-Ruz et al, 2012). The abundance of microplastics in a sand sample was the sum of microplastics in the three filters as expressed as the number of pieces per kg dry sand.

2.3. Microplastic Verification Using FTIR

Several studies have demonstrated there are many false-positive microplastic identifications using the pre-set criteria (Hidalgo-Ruz et al., 2012). To verify the types of materials identified as microplastics beyond simple visual identification, a subset of 29 samples were selected for Fourier transform infrared spectroscopy (FTIR). FTIR spectroscopy was conducted in the Material Science and Engineering Department at Clemson University. Samples were mounted on IRTran[®] windows (ZnSe) and flattened using a “rolling” tool. Spectra were collected using a Thermo-Nicolet Magna 550 FTIR spectrometer equipped with a Thermo-Nicolet Nic-Plan FTIR

microscope. Sixteen scans at a resolution of 4 cm^{-1} were collected for a sample and background in transmission mode (Detector MCT-A, Spectral range $4000\text{-}650\text{cm}^{-1}$).

2.4. Quantification of Urbanization Relative to Microplastic Distribution

To evaluate the potential relationship between urbanization and abundance of microplastics at coastal sites, developed area within a 50 km radius of each sampling site was determined using Esri ArcMap 10.2 software (Esri Co. Ltd, USA). Land cover data were obtained from the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (C-CAP, 2010, 2012; <https://coast.noaa.gov/dataregistry/search/collection/info/ccaphighres>). Layers of developed lands were considered "urbanized".

2.5. Computer Simulation of Offshore Microplastic Transport

Microplastics can be transported to the coast from either "on-shore" (e.g. rivers) or "off-shore" (e.g. by ocean currents) sources. One source of off-shore sources is the transport of particles from other populated areas. To model what cities may serve as sources for some off-shore sourced microplastics to the sampled park sites, the Regional Ocean Modeling System (ROMS) (Shchepetkin and McWilliams 2005) was used to simulate the transport of microplastics released from coastal cities with populations over 100,000 within the sampling region (Table 2, N=26). ROMS uses a system of equations to model a variety of ocean processes (Shchepetkin and McWilliams 2005). A particle-tracking module, Lagrangian Transport (LTRANS) (North et al. 2011), can be used to track passive drifting particles ("drifters") in the ocean, such as microplastics. The simulated drifters in LTRANS are defined as infinitesimally small points, similar to the concept of "points" commonly used in fluid dynamics.

The simulation domain included the Gulf of Mexico, around Yucatan to Belize, north around Florida and the Bahamas, and the East Coast up to Delaware. The model did not include the Caribbean sites VIIS and BUIS. The domain grid has a horizontal grid-spacing of 3 km. The state of ocean surface currents at the initial time and those on the simulation boundaries were generated by downscaling the Hybrid Coordinate Ocean Model (HYCOM) global reanalysis data (Chassignet et al. 2007). A 300-day ocean circulation simulation was conducted starting from November 2012. A data assimilation method called a nudging technique, can perform dynamical relaxation to adjust the model simulation toward observational or analysis states. This nudging technique was used to keep the simulated ocean circulation patterns from deviating from the HYCOM reanalysis. The model simulation represented both the major ocean surface currents, such as the Gulf Stream, Loop Current, Florida Straits Current etc., as well as more local currents or eddies.

Table 2. City, population estimate, and drifter input for coastal cities selected for the ROMS simulation.

City	Population ($\times 10^3$)	Drifters Input Amount (No./day)
Wilmington, NC	100	72
Charleston, SC	120	86
Savannah, GA	136	97
Jacksonville, FL	820	590
Orlando, FL	238	171
Miami and Hialeah, FL	620	446
Tampa, FL	335	241
St. Petersburg, FL	245	176
Mobile, AL	195	140
Gulfport, MS	150	108
New Orleans, LA	343	246
Beaumont, TX	120	86
Houston, TX	2000	1440
Corpus Christi, TX	300	216
Matamoros, Mexico	450	324
Tampico, Mexico	300	216
Tuxpan, Mexico	143	102
Coatzacoalcas, Mexico	305	219
Campeche, Mexico	220	158
Merida, Mexico	777	559
Cancun, Mexico	628	452
Havana, Cuba	2000	1440
Santiago, Cuba	425	306
Holguin, Cuba	277	199
Guantanamo, Cuba	200	144
Nassau, Bahamas	220	158

Throughout the simulation, passive drifters, represented as units of microplastics, were “virtually” released into the ocean water every day at each of the 26 input locations. The number of drifters “released” was proportional to the population of the city. Drifters were “dropped” within a 50 km radius of the city shoreline. Once the drifters were “added” into the coastal waters, they were transported by coastal and ocean currents as passive Lagrangian tracers. We assumed no degradation or property changes in the microplastic drifters within the 300-day simulation. Sample processing was done by counting the number of simulated passive drifters present every three months within a 50 km radius of each of the eighteen NPS sampled sites. The quarterly sampling regime was designed to sample each of the four seasons starting on February 1: (Month day [days into simulation]; February 15 [14 days]; May 15 [103] August 15 [195]; November 15 [287]).

3. RESULTS AND DISCUSSION

3.1 Field Sample Observations

Microplastics were found at every site sampled, but abundance varied among sites (Figures 2 A&B). Samples from FOSU, FOPU, GUIS (HI), and VIIS had the highest counts, whereas samples from DRTO and BICY had the lowest counts (Table 3, Figures 2A&B); their averages were below 60 pieces per kg-sand. Samples from other sites generally ranged from 100 and 300 pieces per kg-sand. Different shapes of microplastics were observed from the samples including fibers, pellets, and irregular shape pieces. Thread-like and fibrous materials were the major types of microplastics observed in many samples (Figure 3). These fibrous pieces were ~20 μm in width and varied highly in length. Lengths ranged from 0.1 to a few that were as large as 11 cm but averaged 1.2 cm (Table 3, Figure 4). Notably, the longest fibrous materials were observed in sites that also had the highest microplastic counts.

Differences in methodologies between studies make direct comparisons challenging. However, this study falls within the ranges observed globally (Lusher 2015). Mathalon and Hill (2014) found 200-800 fibers per kg sediment in Nova Scotia, while our study found microplastic abundance closer to those of Graham and Thompson (2009) along the East Coast of the US. A dominant number of fibers (relative to other shapes) in sandy and sedimentary samples were reported by previous studies (Claessens et al., 2011; Thompson et al., 2004), which is consistent with our findings. The high number of fibers observed suggests that the microplastics at these sites are likely from wastewater, and not just the breakdown of larger ocean debris. It has been shown that up to 80% of microplastics in sediment is from wastewater effluent (e.g., clothes washing) (Browne et al., 2011). Fishing gear is also believed to be an important source of fibers (Browne et al., 2011). This study was not specifically designed to determine the source of microplastics, rather just determine presence and relative abundance. However, based on the high number of fibers observed it is likely that at least a portion of the microplastics sampled at these coastal sites is coming from near or on-shore developed areas as opposed to the open ocean.

Table 3. NPS park unit abbreviation, average number ($\pm$ SD) of microplastics observed, average fiber length for each site sampled.

NPS Abbreviation	Average Number ($\pm$ SD)	Average Length
CAHA	174 $\pm$ 30	3.09
CALO	170 $\pm$ 42	2.34
FOSU	376 $\pm$ 24	3.85
FOPU	414 $\pm$ 53	3.01
CUIS	198 $\pm$ 44	2.26
TIMU	250 $\pm$ 10	2.58
FOMA	182 $\pm$ 35	2.72
CANA	166 $\pm$ 73	2.59
BISC	148 $\pm$ 36	2.35
EVER	122 $\pm$ 21	2.92
DRTO	42 $\pm$ 23	2.80
BICY	56 $\pm$ 15	2.95
GUIS (PK)	300 $\pm$ 75	2.59
GUIS (HI)	366 $\pm$ 48	3.31
GUIS (WS)	306 $\pm$ 57	2.95
PAIS	254 $\pm$ 135	2.51
VIIS	444 $\pm$ 76	2.65
BUIS	102 $\pm$ 65	2.65

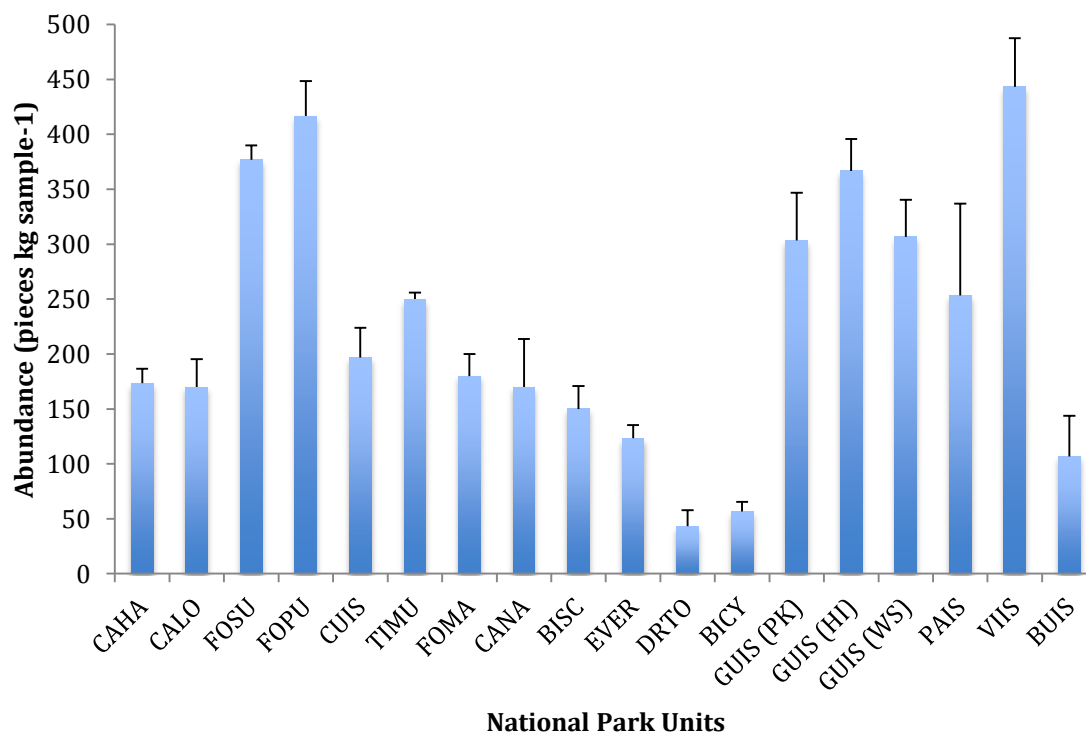


Figure 2A. Abundance (pieces per kilogram of sample) of microplastics for each southeastern NPS site sampled. Error bars indicate the standard error of observations.

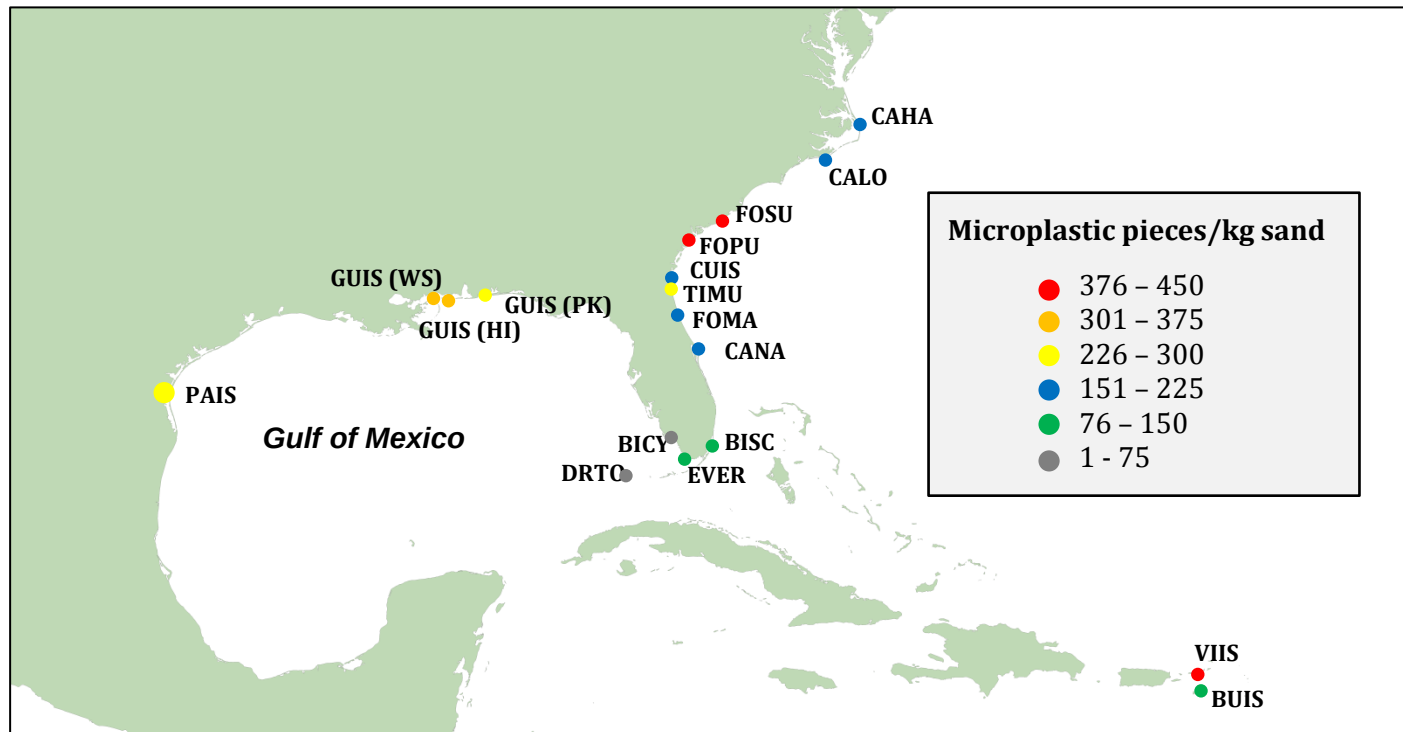


Figure 2B. Distribution of microplastic abundance across 18 NPS sites sampled.

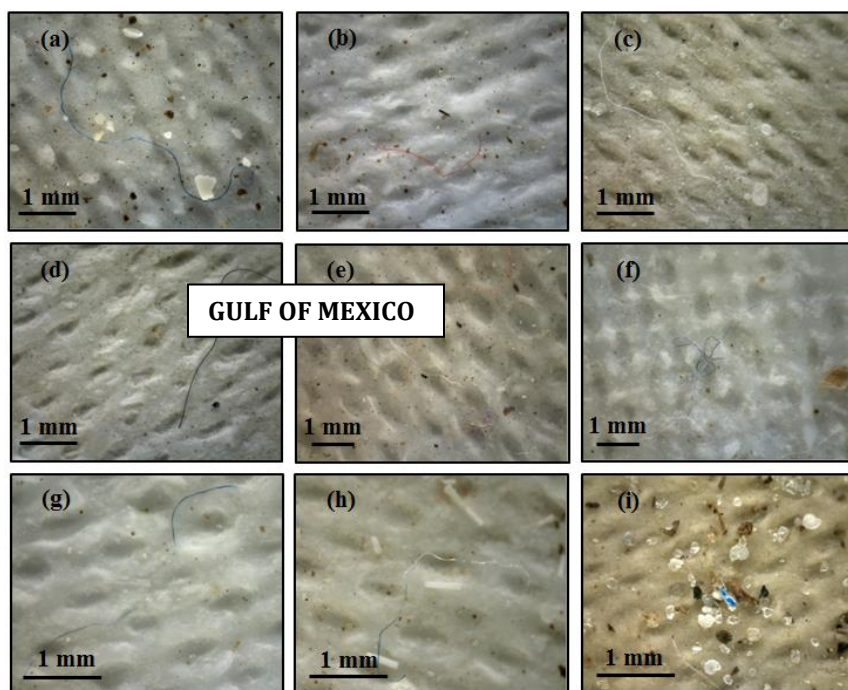


Figure 3. Photographs of visually identified microplastics from various sites. The background of each photograph is glass fiber filter.

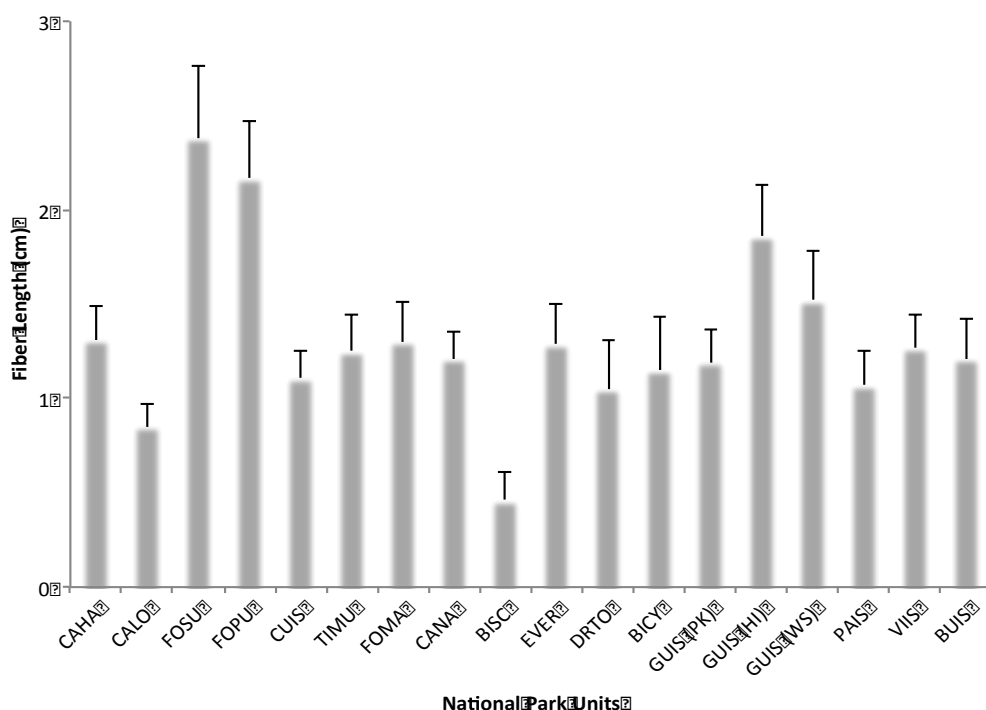


Figure 4. Average fiber length measured in sand samples from 18 NPS sites sampled. Error bars indicate standard deviation.

3.2 FTIR Analysis

Similar to many previous studies (Hidalgo-Ruz et al., 2012), we recognize that not all samples isolated in this study (i.e., density separation followed by visual identification with pre-set criteria –e.g., shape, color, etc.) were plastic polymers. Many false-positive counts resulting in an overestimate of microplastic contamination (Hidalgo-Ruz et al. 2012) have been reported. In some instances up to 70% of pieces identified as microplastics were not plastic polymers (Hidalgo-Ruz et al. 2012). We analyzed 25 fibers and 4 non-fiber particles by FTIR. Of the 29 samples analyzed by FTIR, 7 (24%) were polyethylene terephthalate (PET), one of the most commonly used plastics. All of the PET particles were fibers while 68% of the fibers tested were composed of man-made cellulosic materials such as rayon. One of the non-fiber samples that looked like a microplastic bead was actually composed of silicate. We assume, therefore that the data reported here could be an over or under-estimate of actual microplastic abundances in the beach samples. However, results from field samples still provide a relative abundance and distribution of microplastics or anthropogenic microparticles at the sampled sites.

3.3 Effects of Urbanization on Microplastic Distribution

Wastewater discharge is considered a primary source of plastic debris and microplastics in the marine environment (Browne et al., 2011, Browne 2015) and is generally associated with urban development. To this end, it is hypothesized that sites with a smaller area of urbanization

surrounding the site should have less wastewater input and, in turn, lower abundances of microplastics. To examine the effect of the amount of urbanization on microplastic distribution, the hectares of developed area within a 50 km radius of each site was quantified. A regression analysis of developed area and microplastic abundance showed a weak relationship ($R^2 = 0.24$, $p=0.04$, not shown). However, the site sampled at Virgin Islands National Park (VIIS) is an outlier (are relatively high number of microplastic and very little developed area) and when removed, the regression improved ($R^2 = 0.43$, $p=0.0043$) (Figure 5). The results suggest that 43% of total variation in the number of microplastics among sites could be explained by the relationship between developed area and microplastic count. Therefore, amount of nearby urbanization is likely a factor in the amount of microplastic found at a particular site, but is clearly not the only factor; the sample site itself might confound this result. For example, some sites in the study were on the ocean side of barrier islands such as capes, which might not experience the same level of direct influence from on-shore sources that might be expected at sample sites more directly exposed to urbanized areas, such as FOPU or FOSU. Additionally, some sites (i.e. GUIS, FOSU, and FOPU) are situated directly near large river-estuary systems. These rivers encompass watersheds much larger than the 50 km buffer, which could increase the opportunity for microplastic input from a much larger geographic scale, potentially explaining higher levels of microplastics at these sites.

It is difficult to determine the exact source of microplastics at any particular site, and this study was not designed specifically to answer that question. For example, it is likely that multiple ocean eddies within the Gulf of Mexico influenced the distribution of microplastics at GUIS; ocean currents play important roles on the accumulation and distribution of microplastics at all coastal areas, especially across large regions such as the Gulf of Mexico.

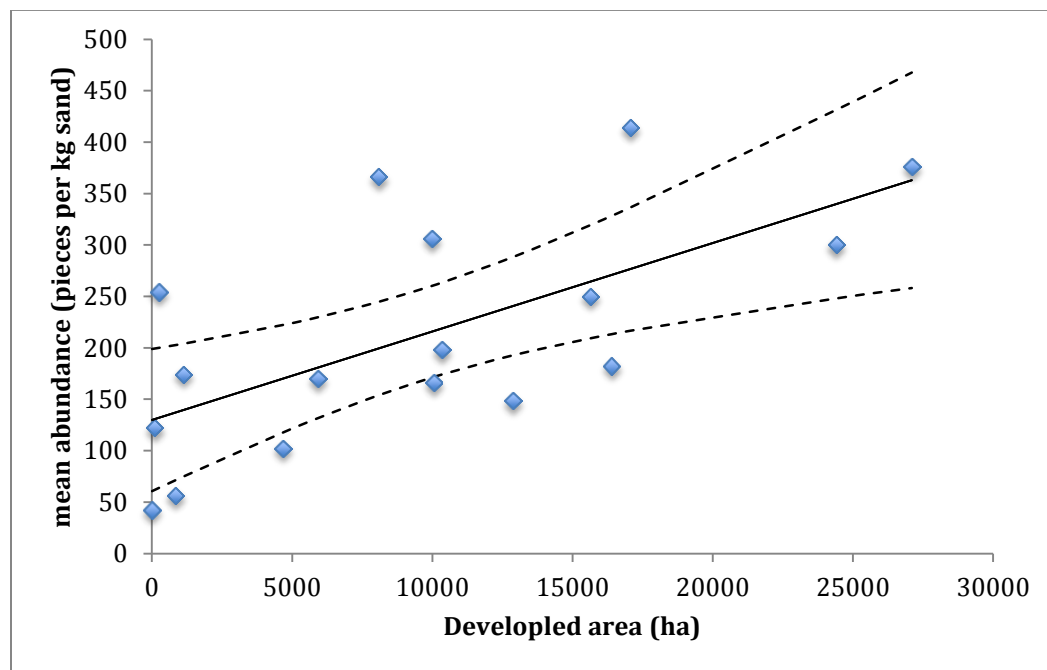


Figure 5. Regression of developed area (ha) in a 50 km buffer and mean abundance of microparticles per kg of sand (solid line) with the 95% confidence interval (dashed line). VIIS, the outlier, was removed from this analysis, when VIIS is included, $R^2 = 0.24$ ($p=0.04$).

3.4 Ocean Current and ROMS Model

Example model outputs of a “snapshot” of drifters from four of the major cities after the 300-day ROMS simulation demonstrate the types of distribution patterns observed (Figure 6). The drifters (Figure 6, red circles) generally followed the ocean currents in the region. For example, microplastics released from Jacksonville only moved north, this is expected due to the presence of the Gulf Stream. In contrast, microplastics released from Houston and Merida circulated within the Gulf of Mexico due to ocean eddies within the Gulf.

The ocean currents may explain the relatively higher numbers of microplastics observed in NPS units (i.e. GUIS-PK, GUIS-HI, GUIS-WS, and PAIS) within the Gulf of Mexico (also see Figure 2 B in Section 3.1). Both the Caribbean Current and the Gulf Stream could affect the movement of microplastics from cities near the Florida Keys. The majority of microplastics released from Havana enter the Gulf of Mexico and only a small portion move north along the Atlantic coast (Figure 6). This seems somewhat surprising as the Gulf Stream is so dominant around the tip of Florida. However, during some parts of the year small localized eddies can be found in the Gulf that drive the distribution of these samples. This result illustrates the importance of local currents. In summary, ROMS simulations demonstrated that ocean currents may be an important factor determining the spatiotemporal distribution of microplastics at coastal areas and likely influence the amount of microplastics on coastal sites.

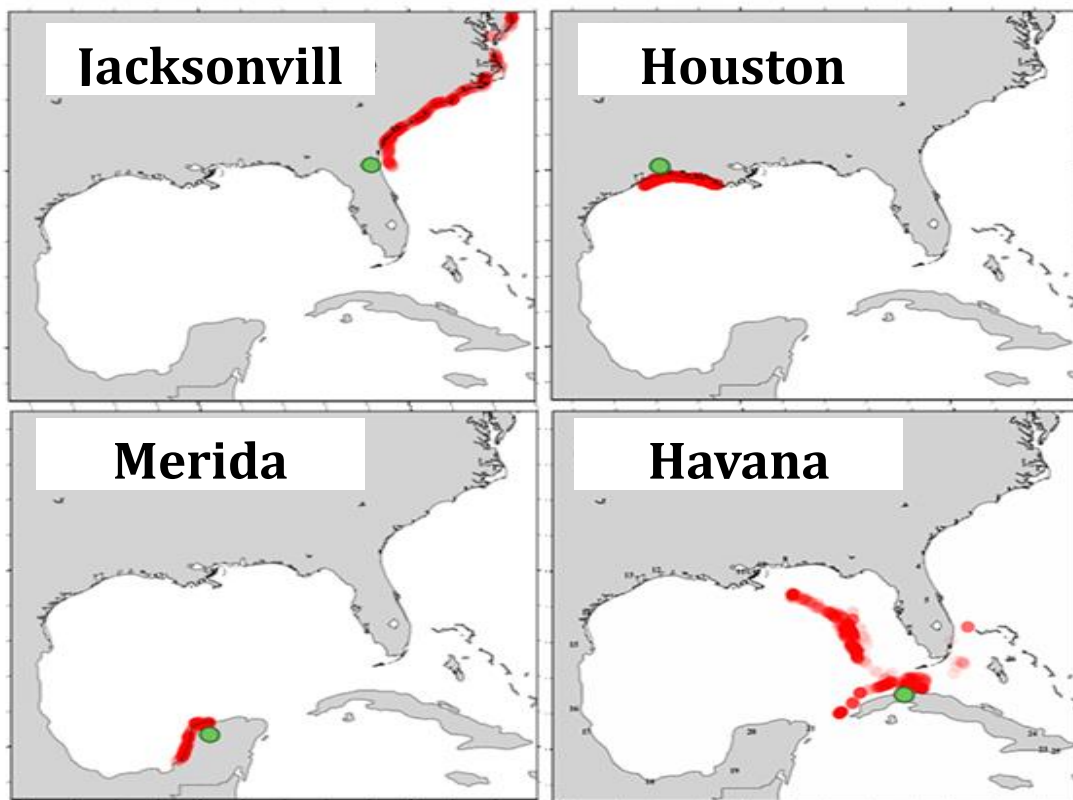


Figure 6. ROMS simulation shows the movement of drifters (red dots) of 4 major cities (green dots) after 300-day simulation.

Potentially contributing cities

The number of “virtual” microplastics within a 50 km radius of the sampling location after ROMS modeling was quantified and the potential city sources (based only on the cities modeled here) for each NPS sample site were identified. Of the 26 cities used for the modeling (Table 2), 12 cities (Havana, Tampico, New Orleans, Gulfport, Mobile, St. Petersburg, Tampa, Orlando, Jacksonville, Savannah, Charleston, Wilmington [Figure 7]), based on the model, potentially contribute drifters to the NPS units. The results of the model generally matched the field observations. Using the data from the day 300 simulation, the number of drifters from the simulation was correlated with number of microplastics observed in the field samples ($R^2 = 0.55$, $p = 0.01$).

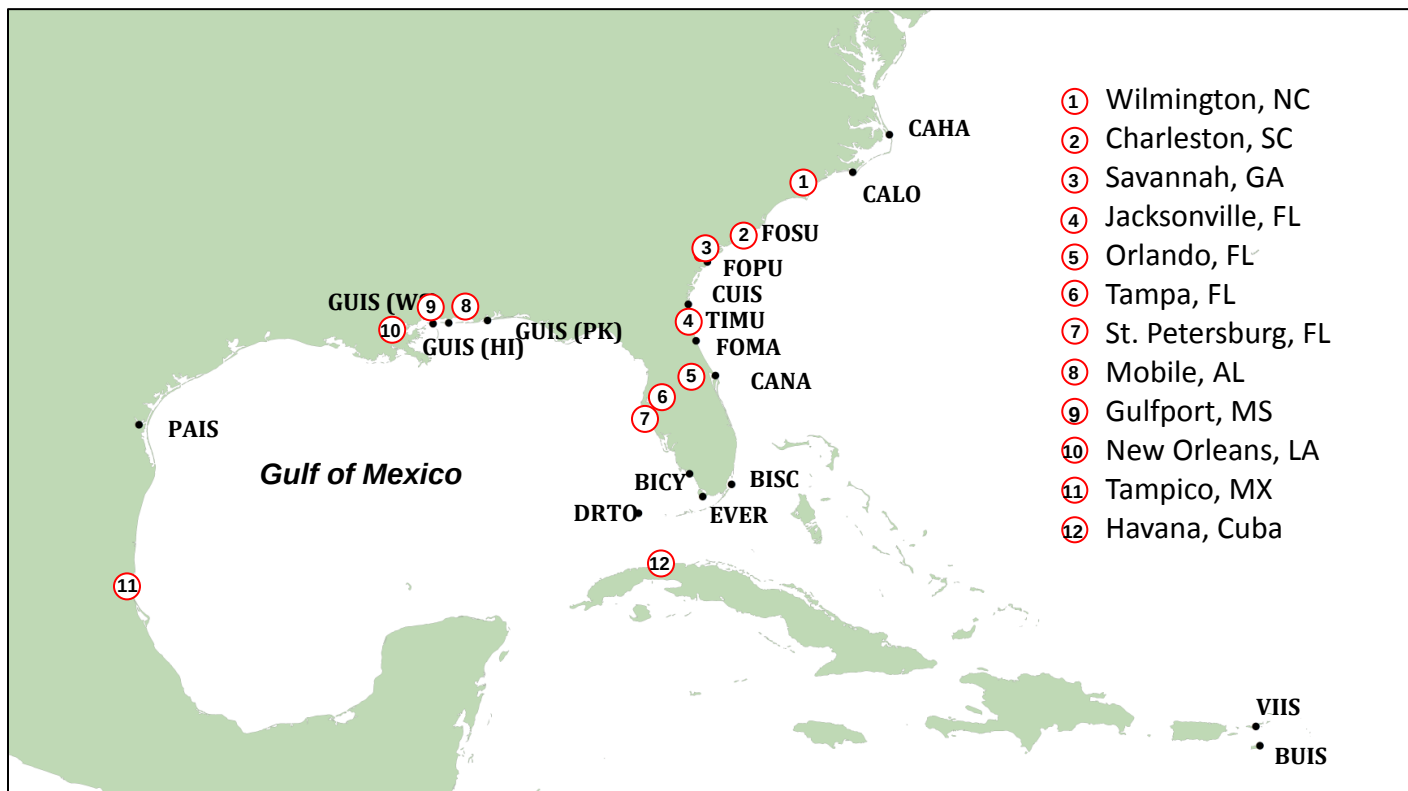


Figure 7. Twelve cities (identified by #) that, based on the ROMs modeling, potentially contribute microplastics to NPS sites sampled.

Predicted contributions to sampled sites

The number of virtual pieces increases over time at any given site, although they can transport out of sites. Additionally, contributing cities influence different regional areas. Jacksonville was one of the major potential microplastic sources for sampled sites along the Atlantic Coast, though it took about 200 modeled days to reach the most northern park unit sampled (CAHA). Jacksonville potentially contributes more to the northern sites at CAHA and CALO than Wilmington, NC which is closer. Savannah and Charleston are predicted to contribute more pieces as well, but their contribution in the 50 km radius seems to vary over time. Orlando was important locally to CUIS, FOMA, TIMU and CANA. The majority of modeled drifters at FOSU and FOPU come from Jacksonville and Orlando (Figure 8, Table 4). This makes sense; these NPS units are north and microplastics would be expected to travel northward along the Gulf Stream.

Gulfport is the main modeled microplastic contributor to the GUIS park units in the Gulf of Mexico, which all had relatively high amounts of microplastics (Figure 2). Cities within the Gulf of Mexico contributed to sites in the Gulf but, even after 300 days, drifters were not observed from the Gulf to sites on the Atlantic coast. This does not mean they never reach these sites, just that if they do, it may take much longer than 300 days. Additionally, these data suggest that cities along the Gulf of Mexico are not major contributors of microplastics to sites on the Atlantic coast relative to more local cities.

Sites in Florida such as BICY and EVER were mostly influenced by drifters from Tampa and St. Petersburg, FL, but it took 100 days for the virtual pieces to reach these areas. These two cities also influenced BISC. Drifters from Havana were only predicted to be transported to DRTO and evidence of transport to this site was not evident until the August sampling period. This is interesting as Havana is so close to the Gulf Stream, we expected it to influence the numbers at BISC or maybe CANA. Interestingly, not all drifters released from the coastal cities were observed at NPS units sampled. Eleven sites did not appear to contribute particles to the coastal sites sampled. These included Miami, Houston, Beaumont, Corpus Christi, Matamoros, Tuxpan, Coatzacoalcos, Merida, Campeche, Cancun, and Nassau. Results suggested microplastics released from these cities may not drift within a 50 km radius from the shore (i.e. our quantification is within 50 km radius of the sampling site) or are removed from the ocean surface by another process. Alternatively, they may take longer than the 300 days modeled here to reach some sites.

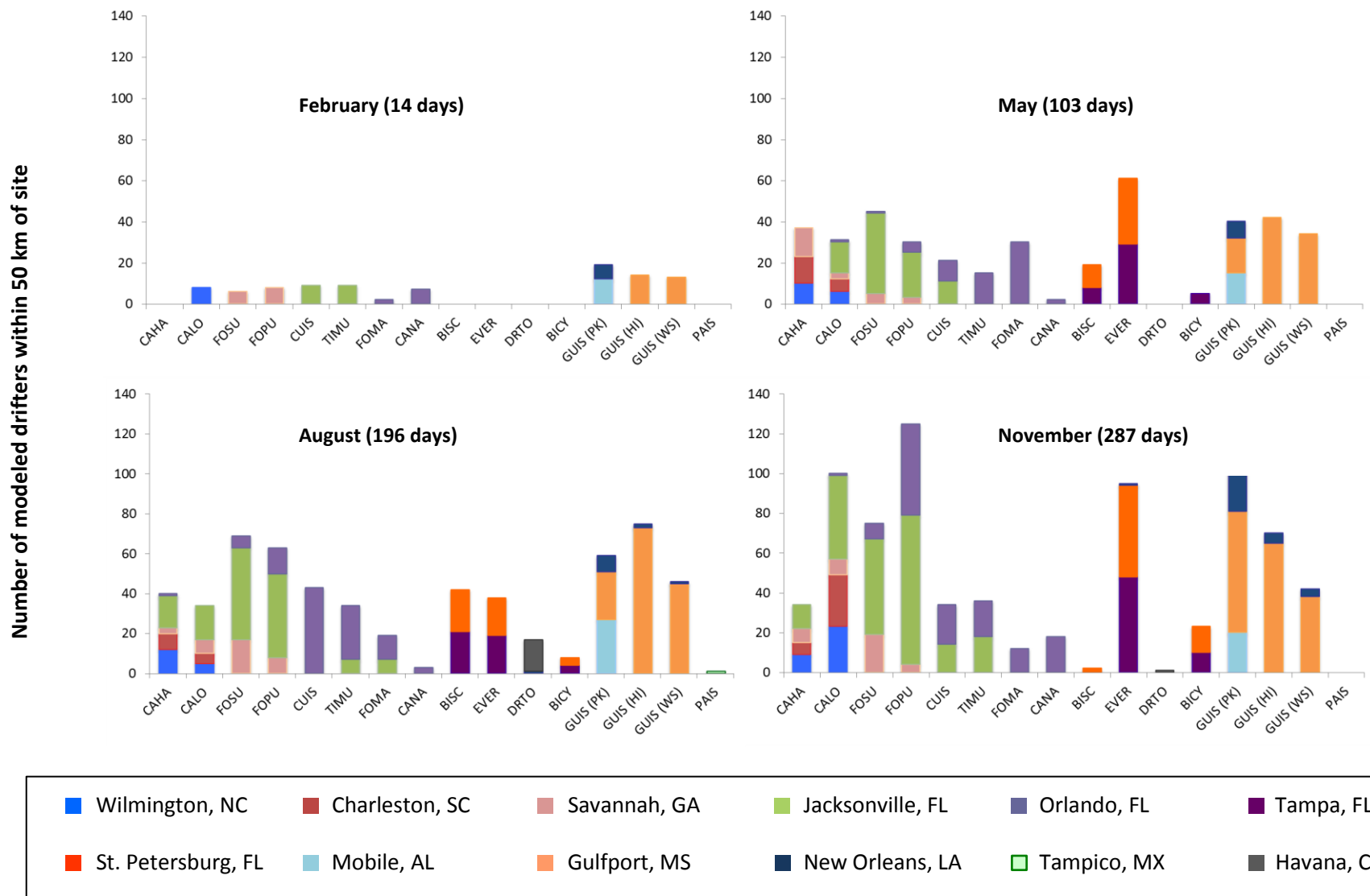


Figure 8. Number of simulated drifters from the major cities found within a 50 km radius of 16 NPS sites based on samples at February 15 (14 days), May 15 (103 days), August 15 (195 days) and November 15 (287 days) during the course of the ROMS simulation. Each color represents the originating major city of the drifters. Only the cities that contribute drifters to the NPS units are included. Cities not included did not contribute drifters to the NPS units based on the model simulation.

Table 4. ROMS drifter sampling period, originating city of modeled drifter and modeled contribution to each drifter receiving site (park codes).

Drifter Sampling Period	Originating City	Drifter Receiving Site (Park Code)															
		CAHA	CALO	FOSU	FOPU	CUIS	TIMU	FOMA	CANA	BISC	EVER	BICY	DRTO	GUIS (PK)	GUIS (HI)	GUIS (WS)	PAIS
February	Wilmington, NC	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Savannah, GA	0	0	6	8	0	0	0	0	0	0	0	0	0	0	0	0
	Jacksonville, MS	0	0	0	0	9	9	0	0	0	0	0	0	0	0	0	0
	Orlando, FL	0	0	0	0	0	0	2	7	0	0	0	0	0	0	0	0
	Mobile, AL	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0
	Gulfport, MS	0	0	0	0	0	0	0	0	0	0	0	0	0	14	13	0
	New Orleans, LA	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
May	Wilmington, NC	10	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Charleston, SC	13	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Savannah, GA	14	3	5	3	0	0	0	0	0	0	0	0	0	0	0	0
	Jacksonville, FL	0	15	39	22	11	0	0	0	0	0	0	0	0	0	0	0
	Orlando, FL	0	1	1	5	10	15	30	2	0	0	0	0	0	0	0	0
	Tampa, FL	0	0	0	0	0	0	0	0	8	29	5	0	0	0	0	0
	St. Petersburg, FL	0	0	0	0	0	0	0	0	11	32	0	0	0	0	0	0
	Mobile, AL	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0
	Gulfport, MS	0	0	0	0	0	0	0	0	0	0	0	0	17	42	34	0
August	New Orleans, LA	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0
	Wilmington, NC	12	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Charleston, SC	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Savannah, GA	3	7	17	8	0	0	0	0	0	0	0	0	0	0	0	0
	Jacksonville, FL	16	17	46	42	0	7	7	0	0	0	0	0	0	0	0	0
	Orlando, FL	1		6	13	43	27	12	3	0	0	0	0	0	0	0	0
	Tampa, FL	0	0	0	0	0	0	0	0	21	19	4	0	0	0	0	0
	St. Petersburg, FL	0	0	0	0	0	0	0	0	21	19	4	0	0	0	0	0
	Mobile, AL	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	0
	Gulfport, MS	0	0	0	0	0	0	0	0	0	0	0	0	24	73	45	0
	New Orleans, LA	0	0	0	0	0	0	0	0	0	0	0	1	8	2	1	0
	Tampico, MX	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Havana, Cuba	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0
November	Wilmington, NC	9	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Charleston, SC	6	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Savannah, GA	7	8	19	4	0	0	0	0	0	0	0	0	0	0	0	0
	Jacksonville, FL	12	42	48	75	14	18	0	0	0	0	0	0	0	0	0	0
	Orlando, FL	0	1	8	46	20	18	12	18	0	0	0	0	0	0	0	0
	Tampa, FL	0	0	0	0	0	0	0	0	0	48	10	0	0	0	0	0
	St. Petersburg, FL	0	0	0	0	0	0	0	0	2	46	13	0	0	0	0	0
	Mobile, AL	0	0	0	0	0	0	0	0	0	0	0	0	20			0
	Gulfport, MS	0	0	0	0	0	0	0	0	0	0	0	0	61	65	38	0
	New Orleans, LA	0	0	0	0	0	0	0	0	0	1	0	0	29	5	4	0
	Havana, Cuba	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

3.4 SUMMARY

The presence of microplastics in the marine environment poses risk to human and wildlife health. Not only is ingestion of the plastic itself a concern, its relatively high surface area and hydrophobic properties can enhance the risk. Microplastics adsorb persistent organic pollutants and other toxic chemicals, enhancing their transportation and bioavailability to marine animals and humans. This study provides a broad geographic assessment of the distribution of microplastics along the Southeast Coast. It provides an opportunity to make general inferences about movement and distribution of microplastics. However, this study was not designed to address the variety of expected environmental impacts on multiple habitat types (e.g. sea floors, corals, etc). (e.g. Lusher 2015, Koelmans 2015) or provide information about impacts to wildlife or humans.

Microplastic contamination is widespread and particles are found at even the most remote sites, which is not completely surprising given their global distribution (eg. Thompson 2015 -review). The quantity varied among sites and their distribution can generally be explained by location and local geography. The presence of large rivers and sites located in areas with larger percentages of developed area were associated with higher numbers of microplastics. This makes sense because wastewater discharges, especially those from coastal cities travelling down major rivers, have been considered a major source of microplastics (Browne et al., 2011, Yonkos et al., 2014). Additionally, ocean currents clearly drive the distribution of microplastics offshore and can aid in predicting risk to coastal sites. It is critical, however, to consider not only large currents such as the Gulf Stream, but also impacts of local eddies on microplastics transport. For example, in this study, virtual drifters released from cities in Texas and Louisiana were predicted to remain in the Gulf of Mexico due to regional eddies.

The overall approach to this project was to sample multiple sites across a broad geographic area at a single point in time. To this end, data produced from this study should be used to gain a better understanding of where microplastics are in the environment. Park units should not use this single study to make strong inferences about risk of microplastics to wildlife and human health at their sites. However, we summarize below the data for each site and provide some suggestions to explain the relative amount of microplastics found at each individual site. **A summary of results for each site sampled is provided in Supplement B.**

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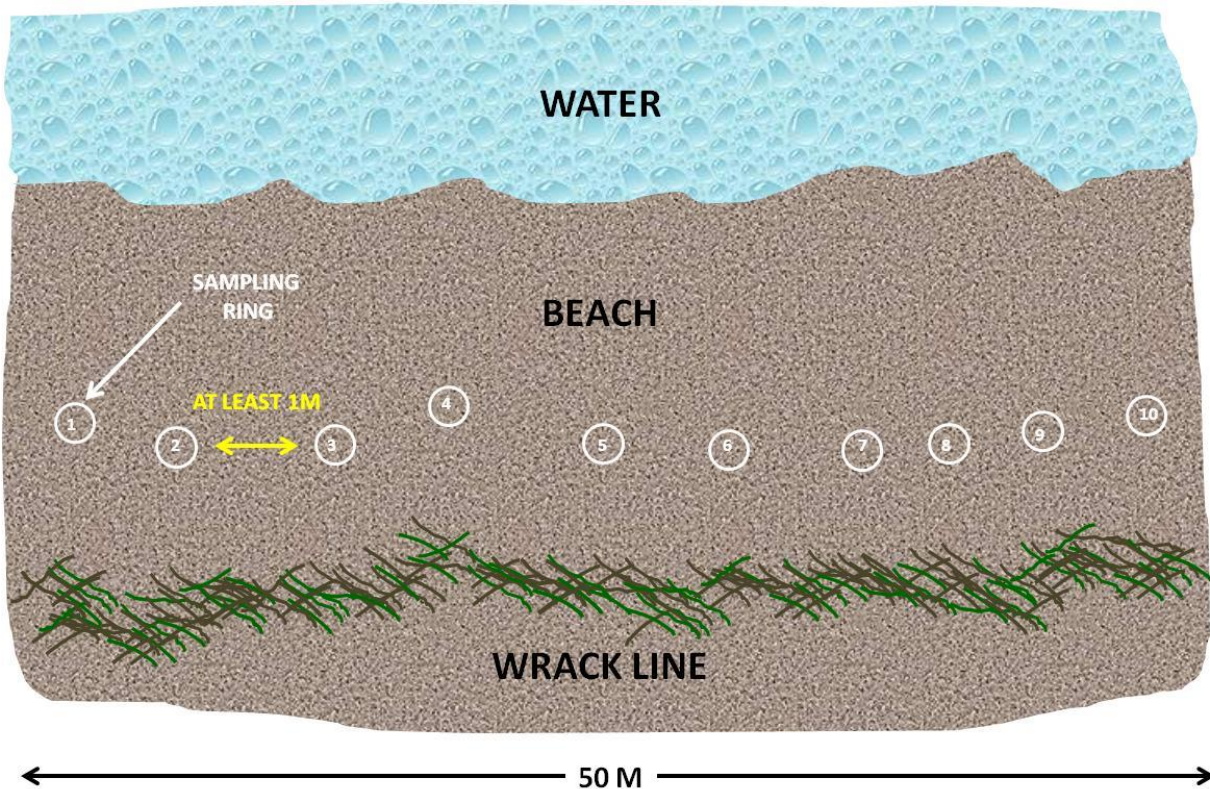
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SUPPLEMENT A

Field Sampling Protocol

Sand Collection Protocol



How to choose a sample location

- Choose a location where the most marine debris is found
 - 10 individual samples taken within a 50 m stretch of beach
 - Samples should be taken above the low tide line and below the high tide line.
 - Make sure it is a low enough tide so there is 1-2 m below the wrack line.
 - As a guideline there should be at least 1 m between placements of the sampling ring. (It is easiest to pick a point and then move a few steps and take another sample until you have 10)
- If you have a piece of debris that is this size of a quarter or less, include it in the samples.
 - You **do not** need to pick up larger samples.
 - Do not pick up anything that may cause you harm.

Step 1 Identify the beach (or coastal zone) most likely to have marine debris. Generally, you will see litter in this area from offshore such as buoys, plastic bottles etc.

Step 2 Take a picture or two of the sampling site and wrack line.

Step 3 Obtain GPS locality data. You can use the default GPS coordinates. Please identify the types of coordinates on the data sheet.

Step 4 Put the sampling ring on the selected sampling point and press it into the sand until the top edge parallel with the sand surface (Figure 1).

Step 5 Use a non-plastic sampling spade (or spoon) to scoop out sand within the ring (Figure 2). Do not collect sand below the bottom edge of the ring.

Step 6 Transfer the sand sample into a prepared aluminum foil bag (7×12 in). After filling, fold the opening 3 to 4 times to seal the bag (Figure 3). The area in the ring should be sampled entirely (Figure 4).

Step 7 Put the wrapped foil bag into a labeled paper bag (Figure 5a) and place the paper bag into ziplock bag; squeeze the air out press to close it (Figure 5b).

Step 8 Package these bags in the same USPS box and use the enclosed address label and stamps for shipping (Figure 6).



Figure 1



Figure 2



Figure 3



Figure 4



Figure 5a



Figure 5b



Figure 6

SUPPLEMENT B

Individual Park Summaries

Approach

A brief explanation of results for each park site sampled is provided here in the order (generally north to south) used throughout the study (Table B1).

Table B1. NPS unit sampled and geographical coordinates (Lat. Lon.).

NPS Unit	Latitude N.	Longitude W.
Cape Hatteras National Seashore	35°46'39.68"	75°32'05.96"
Cape Lookout National Seashore	34°40'17.60"	76°36'43.70"
Fort Sumter National Monument	32°45'07.19"	79°52'31.00"
Fort Pulaski National Monument	32°01'53.00"	80°53'34.80"
Cumberland Island National Seashore	30°46'54.88"	81°27'21.91"
Timucuan Ecological & Historical Reserve	30°34'24.50"	81°26'34.30"
Fort Matanzas National Monument	29°42'39.31"	81°13'34.50"
Canaveral National Seashore	28°41'08.06"	80°39'15.15"
Biscayne National Park	25°28'51.18"	80°10'46.20"
Everglades National Park	25°07'20.88"	81°01'54.82"
Big Cypress National Preserve	25°47'31.30"	81°25'10.00"
Dry Tortugas National Park	24°37'57.99"	82°55'17.76"
Gulf Islands National Seashore - Perdido Key	30°18'34.70"	87°22'01.96"
Gulf Islands National Seashore - Horn Island	30°13'56.31"	88°30'39.47"
Gulf Islands National Seashore - West Ship Island	30°12'46.84"	88°58'18.91"
Padre Island National Seashore	27°14'09.90"	97°37'31.50"
Virgin Islands National Park	18°21'22.13"	64°44'45.37"
Buck Island Reef National Monument	17°47'23.14"	64°37'32.34"

The overall approach to this project was to sample multiple sites across a broad geographic area at a single point in time. To this end, data produced from this study should be used to gain a better understanding of where microplastics are in the environment. Park units should not use this single sample/study to make strong inferences about risk of microplastics to wildlife and human health at their sites. However, summarized below are the data for each site provided individually. Some suggestions are given to explain the relative amount of microplastics observed. Exact sample site locations are indicated by red dots on the park maps provided. Park four letter acronyms are provided for each site.

Data for each park unit are provided (Table B2, an example) and include:

- Average number of microplastic pieces found in each kg of dry sand
- Site rank (low to high: 0-25%, 26-50%, 51-75%, and 76-100%) - this value represents the overall relative rank from low to high (low having the fewest number of microplastic pieces per kg dry sand) of the samples examined in this study
- Percentage of items as pieces – this is the percentage of pieces of plastic that are not fibers
- Percentage of items as fibers
- Percent of developed area within 50 km radius – based on C-CAP data (as discussed in text) the percentage of land cover defined as “developed” or “urbanized”.

Table B2. Measures of microplastics and associated values for individual sites.

Measure	Value
Average number of microplastic pieces	X ± Y pieces/ kg dry sand
Site rank (low to high)	0 - 25%
Percentage of items as pieces	X%
Percentage of items as fibers	X%
Percent of urban area within 50 km radius	X%

A “Discussion” is provided for each site. The purpose of this section is to provide a very brief explanation of the results for a single site and identify potential explanations for the results.

Park Summaries

Cape Hatteras National Seashore (CAHA)



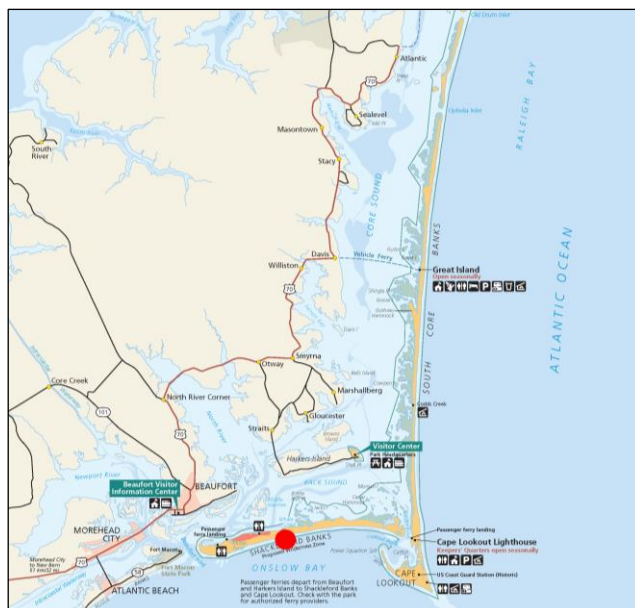
Measure	Value
Average number of microplastic pieces	174 ± 30 pieces/ kg dry sand
Site rank (low to high)	26-50%
Percentage of items as pieces	41.4%
Percentage of items as fibers	58.6%
Percent of urban area within 50 km	0.004%

Discussion

This site is fairly remote and near very little urbanization. The beach sampled is located on the outer portion of a barrier island. However, there is potential for input of microplastics from the Chowan River which runs into Abermarle Sound and possibly the Pamlico River which runs into Pamlico Sound.

The number of microplastics found is moderate relative to other sites sampled. It is likely that microplastics that are transported down the rivers are trapped in the bays to a degree. The modeled contribution of plastics from other cities via ocean currents suggests that sources of microplastics could include Wilmington, NC; Charleston, SC; Savannah, GA; Jacksonville, FL and a very small portion from Orlando, FL. Generally, it is expected that offshore microplastics are transported northward via the Gulf Stream.

Cape Lookout National Seashore (CALO)

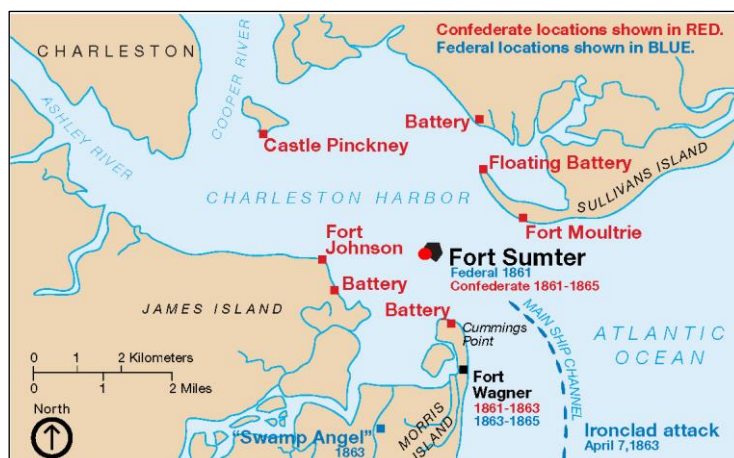


Measure	Value
Average number of microplastic pieces	170 ± 42 pieces/ kg dry sand
Site rank (low to high)	26-50%
Percentage of items as pieces	41.2%
Percentage of items as fibers	58.8%
Percent of urban area within 50 km	0.07%

Discussion

This sample site is located in a relatively remote area surrounded by low levels of urbanization. This area is connected hydrologically to the Neuse, Newport, and North Rivers. However, the sample location itself is on the ocean side of the island sampled. It is possible therefore, that plastic via wastewater does not readily reach the sample site. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include Wilmington, NC.; Charleston, SC.; Savannah, GA.; and Jacksonville, FL. As with other sites sampled in this area, it is generally predicted that microplastics are transported northward via the Gulf Stream.

Fort Sumter National Monument (FOSU)

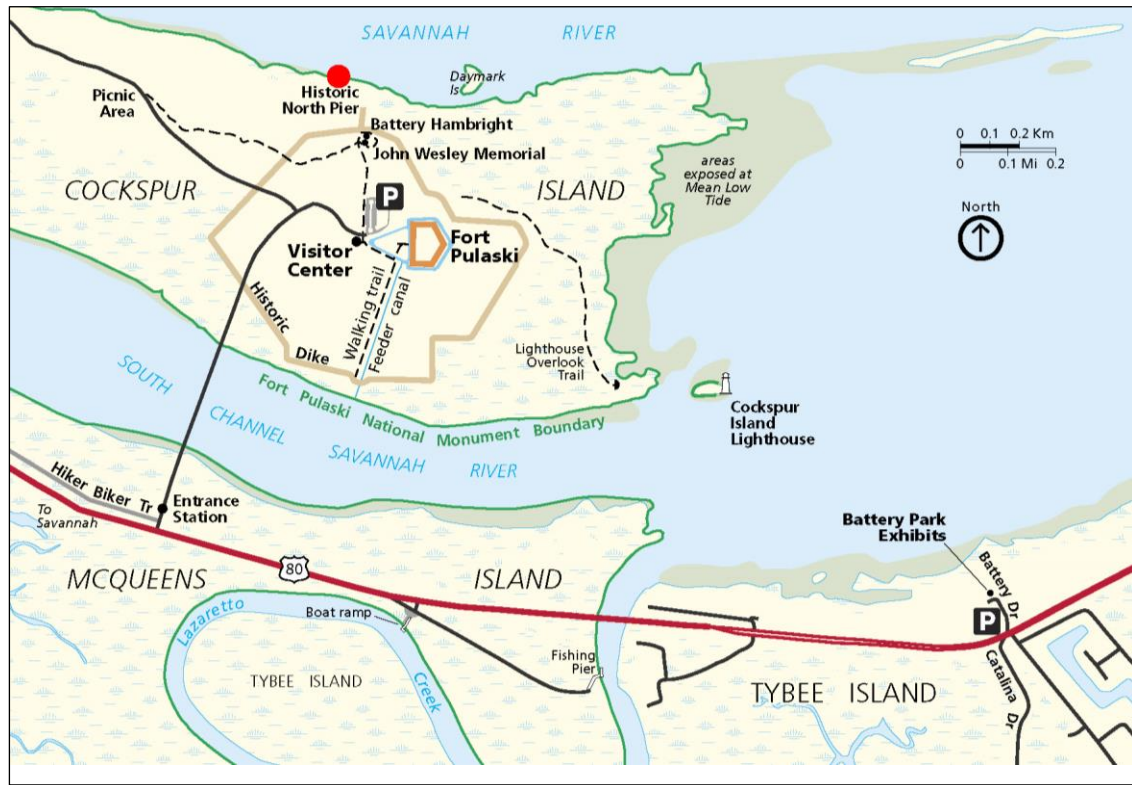


Measure	Value
Average number of microplastic pieces	376 ± 24 pieces/ kg dry sand
Site rank (low to high)	76-100%
Percentage of items as pieces	79.8%
Percentage of items as fibers	20.2%
Percent of urban area within 50 km	0.22%

Discussion

Fort Sumter National Monument is located on a small island in Charleston Harbor SC. The City of Charleston is nearby and both the Ashley and Cooper Rivers drain into the harbor. The number of microplastics found at this site is high relative to other sites sampled in this study. This is expected due to its location to nearby rivers and opportunity for wastewater input. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include Orlando and Jacksonville, FL. as well as Savannah, GA. It is important to note that the transport of the drifters was based on the assumption that they were “dropped” offshore 50 km from the city. This explains the lack of modeled contribution from the city of Charleston.

Fort Pulaski National Monument (FOPU)



Measurement	Value
Average number of microplastic pieces	414 ± 53 pieces/ kg dry sand
Site rank (low to high)	76-100%
Percentage of items as pieces	75.4%
Percentage of items as fibers	24.6%
Percent of urban area within 50 km	0.21%

Discussion

This site is located along the Savannah River and has a relatively large amount of urbanized area nearby. The number of microplastics observed at this site is relatively high when compared to other sites sampled in this study. Microplastics are likely traveling down the Savannah River to the Fort Pulaski estuary. The modeled off-shore contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include not only Savannah, GA but the coastal area east of Orlando and the city of Jacksonville, FL. The modeled off-shore contribution from Savannah is low. This is expected based on the modeled location of the off-shore drifter (50 km offshore).

Cumberland Island National Seashore (CUIIS)



Measure	Value
Average number of microplastic pieces	198 ± 44 pieces/ kg dry sand
Site rank (low to high)	51-75%
Percentage of items as pieces	43.3%
Percentage of items as fibers	56.6%
Percent of urban area within 50 km	0.18%

Discussion

This site is located on an island east of the Cumberland River. The number of microplastics is moderately high despite the low percentage of urban area immediately surrounding the site. Some plastics are likely moving to the site from the Saint Mary's and Amelia Rivers. Most modeled offshore drifters are transported from the city of Jacksonville, FL. and later in the modeled time period, the coastal area east of Orlando, FL.

Timucuan Ecological and Historic Preserve (TIMU)

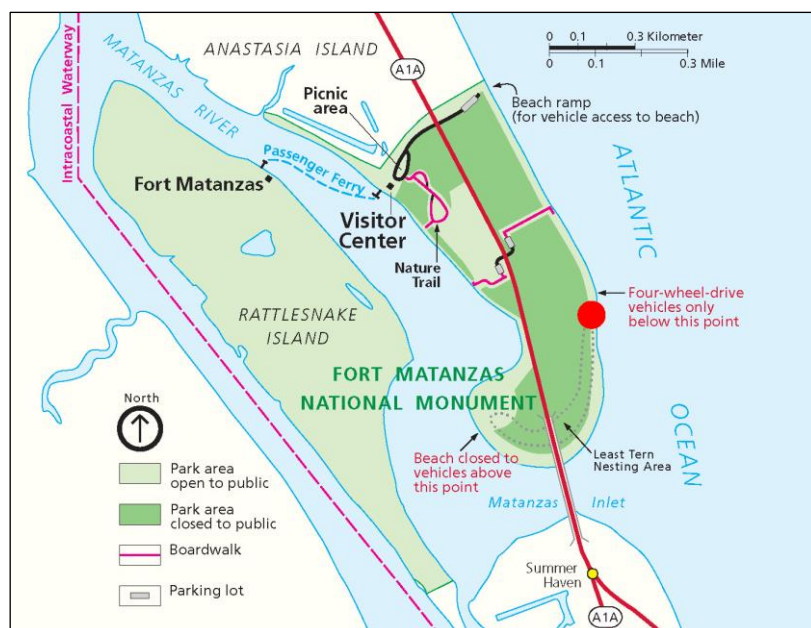


Measure	Value
Average number of microplastic pieces	250 ± 10 pieces/ kg dry sand
Site rank	51-75%
Percentage of items as pieces	66.4%
Percentage of items as fibers	33.6%
Percent of urban area within 50 km	7.97%

Discussion

The number of microplastics found at this site was moderately high. This is expected; the location of this site at the base of the St. Johns River and near to the city of Jacksonville. It is likely that microplastics are traveling down the river to this site. Most modeled offshore drifters are transported from the city of Jacksonville FL, and the coastal area east of Orlando, FL.

Fort Matanzas National Park (FOMA)



Measurement	Value
Average number of microplastic pieces	182 ± 35 pieces/ kg dry sand
Site rank (low to high)	26-50%
Percentage of items as pieces	57.1%
Percentage of items as fibers	42.9%
Percent of urban area within 50 km	0.18%

Discussion

This relatively small site is not adjacent to a large city but is located on the Matanzas River. The abundance of microplastics is in the mid-range relative to that found at other sites sampled in this study. Microplastics are likely travelling down the Matanzas River to this site. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include Jacksonville, FL. and the coastal area east of Orlando, FL.

Canaveral National Seashore (CANA)



Measure	Value
Average number of microplastic pieces	166 ± 73 pieces/ kg dry sand
Site rank (low to high)	26-50%
Percentage of items as pieces	38.6%
Percentage of items as fibers	61.5%
Percent of urban area within 50 km	0.17%

Discussion

This site is within an area with relatively low levels of urbanization. However, the Indian River and Banana River may transport microplastics from surrounding urbanized areas. The site sampled is on the ocean side of the spit off of Mosquito River Lagoon. To this end, the direct transport of microplastics from the rivers to this site may be limited. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include the coastal area east of Orlando, FL. and surrounding areas.

Biscayne National Park (BISC)



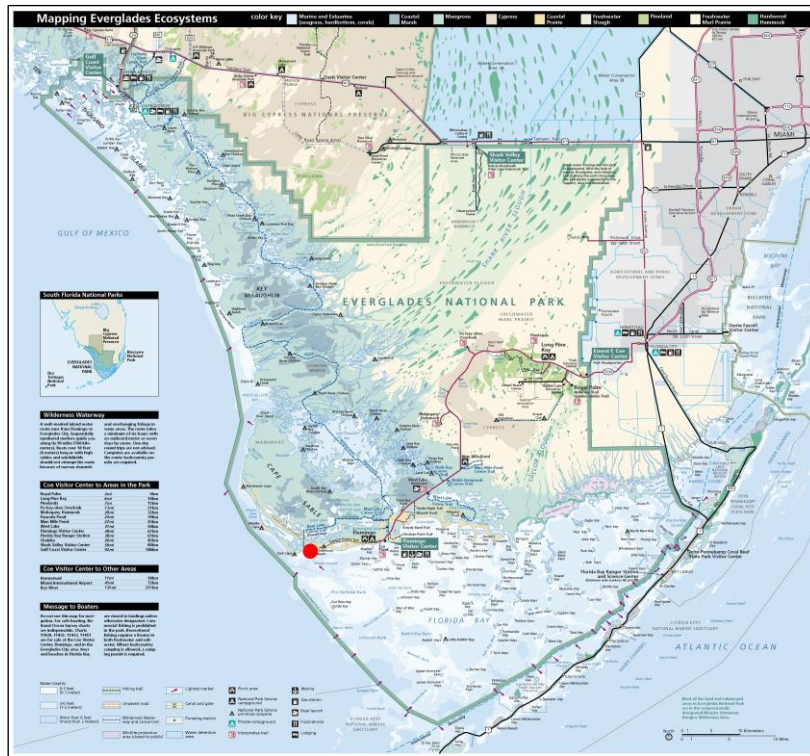
Measure	Value
Average number of microplastic pieces	148 ± 36 pieces/ kg dry sand
Site rank (low to high)	26-50%
Percentage of items as pieces	87.8%
Percentage of items as fibers	12.2%
Percent of urban area within 50 km	0.36%

Discussion

This park is near the highly-urbanized area of Miami, Florida and the Miami River provides freshwater input into Biscayne Bay. However, the area surrounding the sample site itself is not highly urbanized.

The average number of microplastics found at this site is low to moderate relative to other sites. This is somewhat surprising due to the location of the park near high levels of urbanization. However, the sample site is located on the outer portion of Biscayne Bay. To this end, microplastics are possibly trapped within the inner Bay area and the majority of microplastics present at the sample site may have been transported via ocean currents. Most of the microplastics consist of pieces rather than fibers which suggests the possibility that the source of microplastics include degraded debris from larger sources (e.g. plastic bottles) rather than from wastewater. Of the cities modeled for transport of microplastics, Tampa and Saint Petersburg, Fl., are expected to contribute microplastics to this site. A more thorough understanding of the presence of microplastics could be obtained by sampling in and outside of the bay.

Everglades National Park (EVER)



Measure	Value
Average number of microplastic pieces	122 ± 21 pieces/ kg dry sand
Site rank (low to high)	0-25%
Percentage of items as pieces	41.0%
Percentage of items as fibers	59.0%
Percent of urban area within 50 km	0.01%

Discussion

Everglades National Park is expansive and located at the southern tip of Florida. There is very little urbanization near the sampled site and, expectedly, very few microplastics were found there. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include St. Petersburg and Tampa, Fl.

Big Cypress National Preserve (BICY)

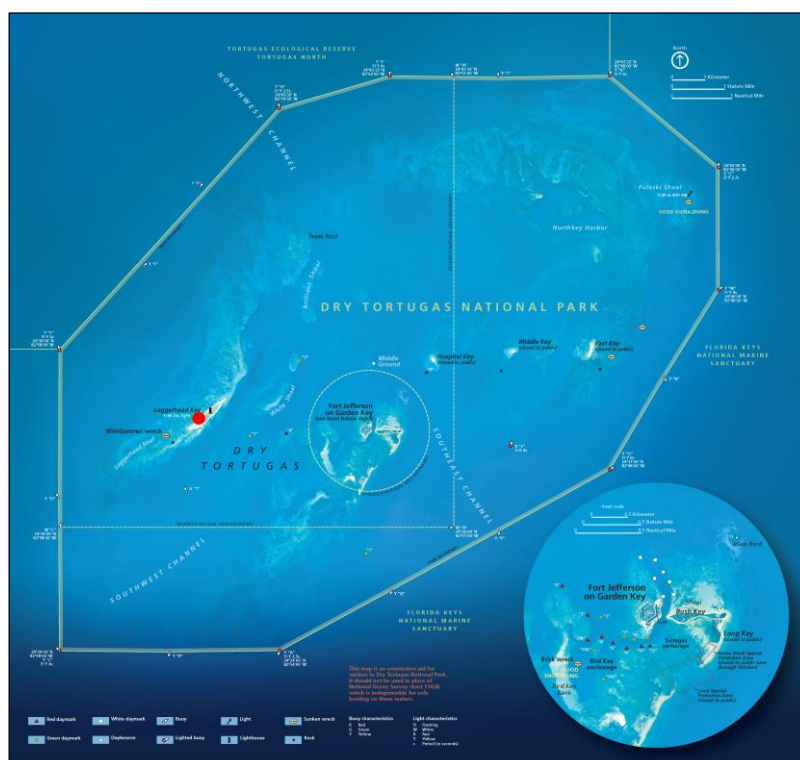


Measure	Value
Average number of microplastic pieces	56 ± 15 pieces/ kg dry sand
Site rank (low to high)	0 - 25%
Percentage of items as pieces	39.3%
Percentage of items as fibers	60.7%
Percent of urban area within 50 km radius	0.05%

Discussion

The site sampled at this park is relatively remote. The surrounding area has very little urbanization and there is no large river transporting wastewater material into the area near the sample site. As expected, the average number of microplastics found at this site is relatively low compared to other sites sampled. This makes sense based on the local geography. Of the nearby cities modeled for transport of microplastics, contributions of microplastics via ocean currents could be transported from Tampa and St. Petersburg, FL.

Dry Tortugas National Park (DRT0)



Measure	Value
Average number of microplastic pieces	42 ± 23 pieces/ kg dry sand
Site rank (low to high)	0-25%
Percentage of items as pieces	19.0%
Percentage of items as fibers	81.0%
Percent of urban area within 50 km	0.001%

Discussion

Dry Tortugas National Park is located on a remote island over 100 km west of Key West, Florida. Expectedly, very few microplastics were observed at this site. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents include mostly Havana, Cuba and a small number from near New Orleans, LA.

Gulf Island National Seashore (GUIS)



Measure	Values by Site		
	West Ship Island	Horn Island	Perdido Key
Average number of microplastic pieces	306 ± 57 pieces/kg dry sand	366 ± 48	300 ± 75
Site rank (low to high)	51-75%	76-100%	51-75%
Percentage of items as pieces	78.4%	75.4%	70.7%
Percentage of items as fibers	21.6%	24.6%	29.3%
Percent of urban area within 50 km	0.19%	0.13%	0.26%

Discussion

This site is located in the Gulf of Mexico and three samples were taken. Two samples were obtained from barrier islands (Horn Is., Ship Is.) and a third sample was taken from the shore of Perdido Key. All samples are similar in the amount of urbanization nearby. The amount of microplastics found in the samples. All samples contain relatively high numbers of microplastics compared to other sites sampled in this study; Horn Island had the greatest of the three. Sources of microplastics into these sites could include input from multiple rivers including the Mississippi and Alabama Rivers. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include New Orleans, LA., Gulf Port, MS., and Mobile, AL. Additionally, the large amount of fisheries in the Gulf of Mexico could contribute microplastics due to degraded fishing gear such as nets and lines.

Padre Island National Seashore (PAIS)

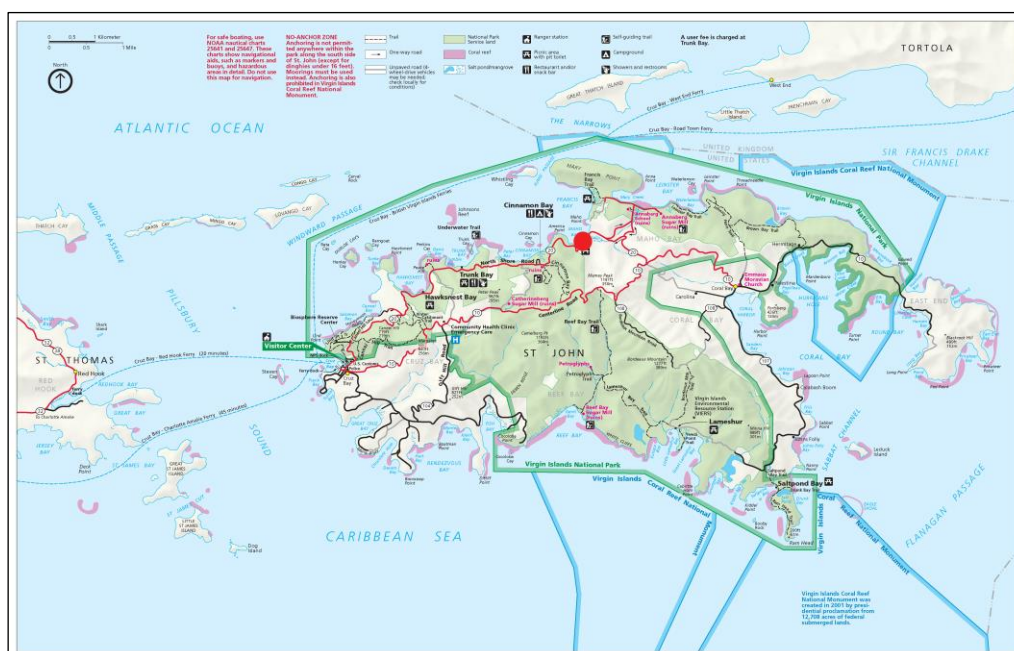


Measurement	Value
Average number of microplastic pieces	254 ± 135 pieces/ kg dry sand
Site rank	51-75%
Percentage of items as pieces	71.7%
Percentage of items as fibers	28.4%
Percent of urban area within 50 km	0.04%

Discussion

This site is located on the far western portion of the Gulf of Mexico. Although not directly near a highly-urbanized area, the number of microplastics found at this site is relatively high compared to other sites sampled in this study. Input from the mainland may come from nearby Corpus Christi, TX. The modeled contribution of plastics from other cities suggests that sources of microplastics via ocean currents could include Tampico, MX. Additionally, as with other sites in this study, the potential for a large amount of degraded fisheries-based gear in the Gulf of Mexico could contribute microplastics to this site.

Virgin Islands National Park (VIIS)



Measure	Value
Average number of microplastic pieces	444 ± 76 pieces/ kg dry sand
Site rank	76-100%
Percentage of items as pieces	76.6%
Percentage of items as fibers	23.4%
Percent of urban area within 50 km	0.13%

Discussion

The site sampled is located on the shore of a bay on Saint John, VI. Despite the relatively small amount of urbanization in the area, the amount of microplastics found was high compared to other sites. The transport of microplastics via ocean currents was not modeled for this site. However, there are no large rivers in the area so input from the mainland sources (ie wastewater treatment plants, and septic systems) is likely traveling via local currents around the island.

Buck Island Reef National Monument (BUIS)



Measure	Value
Average number of microplastic pieces	102 ± 65 pieces/ kg dry sand
Site rank (low to high)	0-25%
Percentage of items as pieces	39.2%
Percentage of items as fibers	60.8%
Percent of urban area within 50 km	0.05%

Discussion

This park site is on a small island located off shore of St. Croix, VI. There is no development on the site itself and there is very little development in the area immediately surrounding the site. There is no large river nearby to transport wastewater to this site. To this end, that the relative amount of microplastics found at this site is low, is expected. The transport of microplastics via ocean currents was not modeled for this site.