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The Microscopic Threat with a Macroscopic Impact: Microplastics Along the Southeast Florida Reef Tract

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HALMOS COLLEGE OF NATURAL SCIENCES AND OCEANOGRAPHY

THE MICROSCOPIC THREAT WITH A MACROSCOPIC IMPACT: MICROPLASTICS ALONG THE SOUTHEAST FLORIDA REEF TRACT

By:

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ABSTRACT

Microplastics have been found in large quantities in marine water samples and biota around the world. These microplastics, when present in the marine environment, decrease water quality and negatively impact marine life. This research quantified and classified marine plastic pollution along the Southeast Florida Reef Tract (SEFRT), in order to understand how this plastic is entering the ocean and the scope of the microplastic contamination in the northern SEFRT. Surface and bottom water samples were collected at 7 sites along the SEFRT for 6 months, filtered, and microscopically analyzed for microplastic content and composition using Fourier-transform infrared spectrophotometry (FTIR). Classification groups were created, and included pieces, shards, clusters, and fibers of 9 colors; fibers were the most common, as was the color blue. Data regarding total plastics at depth, sites, and months was analyzed. There were significantly more total plastics in surface samples than in bottom samples, but no significant difference in plastic totals from month to month or between sites. Overall, there was no significant difference between depth, location, and month combined. FTIR polymer analysis was used to evaluate the source of this plastic pollution, and seven plastic polymers were successfully identified. Five contaminants adsorbed to the plastic particles were also identified. Based on composition of observed polymers, it is likely that these plastics entered the ocean as both primary and secondary microplastics. A multi-faceted approach is necessary to halt the insertion of microplastics into the ocean; preventing microplastics from entering the drain and sewage systems as well as eliminating larger plastic debris.

Keywords: Microplastics, outfalls, congregators, pollution, FTIR, coral reefs

INTRODUCTION

Humans rely on global oceans for important economical, spiritual, physical, medical, and environmental services (Reid et al. 2005, Halpern et al. 2008, Valdés et al. 2009). They are also extremely biologically diverse (Reid et al. 2005, Valdés et al. 2009). However, the oceanic environment which humanity relies so heavily upon, is under threat. Increased carbon dioxide in the atmosphere is causing ocean warming and acidification which in turn decreases marine animal functioning, bleaches corals, and alters vital chemistry that sustains healthy marine ecosystems (Pörtner 2008). Overfishing has caused trophic shifts in the ocean, altering functionality of marine systems (Coll et al. 2008). And now, a new threat has emerged: microplastic pollution.

Microplastics are typically between <1mm and <10 mm in length, depending on the classification group (Cole et al. 2011). There are many different types of plastics, but the main constituents of global total plastic production are 24% polypropylene (PP), 21% low-density polyethylene (LDPE), 19% poly vinyl-chloride (PVC), and 17% high-density polyethylene (HDPE). All other types of plastics make up 19% of total plastic production (Andrady 2011). All in all, PP and PE make up the majority of the plastic products in circulation (Andrady 2011).

Microplastics can also be classified depending on the origin and development of the plastic pieces and are typically characterized as primary and secondary plastics. The term primary plastic is used to describe plastics that originate from scrubbers in facial scrubs, cosmetics, or cleansers that get washed down the drain (Fendall & Sewell 2009, Cole et al. 2011). These plastics can also enter wastewater through domestic and commercial laundering, which may release thousands of fibers in every load of laundry (McIlwraith et al. 2019). These plastics may enter the ocean via runoff, combined sewage overflow events, or through "outfall" sites: areas along the SE Florida coast where partially treated sewage is dumped into the ocean (Andrady 2011, Doughty & Eriksen 2014, Van Velzer 2017). Waste treatment plants do not have the infrastructure to be able to successfully remove all plastics, so wastewater that enters the ocean contains plastics (Fendall & Sewell 2009, Doughty & Eriksen 2014). The term secondary plastic is used to describe plastic that originates from larger plastics, such as fragments of fishing nets, plastic objects, and ropes (Lebreton et al. 2018). This category may also include fragments of plastics from beaches or coastal areas that have been degraded by weather, leading to

embrittlement and microcracking (Andrady 2011). Beach litter accounts for 80% of oceanic plastic debris (Andrady 2011).

Microplastics have become a topic of increasing interest in recent years, with scientific studies identifying plastics in unusual and remote locations including the high Alps, Arctic snow and ice, rain, the deep sea, topsoil, and even the air (Cauwenberghe et al. 2013, Gasperi et al. 2015, Dris et al. 2016, Cai et al. 2017, Bergmann et al. 2019, Choy et al. 2019, Wang et al. 2019, Wetherbee, Baldwin, & Ranville 2019). Microplastics have also been found in human lungs and stool, entering the body through crops, air, and water (Pauly et al. 1998, Dris et al. 2015, Gasperi et al. 2015, Tyree & Morrison 2017, Catarino et al. 2018, Gündoğdu 2018, Parker 2018).

Although the effects of microplastics on marine organisms and the general oceanic environment has yet to be fully quantified and understood, it is known that there has been a recent rapid accumulation of microplastics in the world oceans (Andrady 2011, Cole et al. 2011, Lebreton et al. 2018). The most obvious example of this plastic accumulation is the Great Pacific Garbage Patch, a "floating island" the size of Texas in the Pacific Ocean (Lebreton et al. 2018). Here, microplastics make up 8% of the total plastic mass in the patch and account for 94% of plastic pieces floating in the area, which equates to about 6,400 metric tons (Lebreton et al. 2018). These plastics are persistent and do not biodegrade, and as such are frequently ingested by marine life (Tokiwa et al. 2009, Andrady 2011). When they are present in an oceanic ecosystem, microplastics reduce the health of organisms living there and negatively impact the general oceanic environment (Andrady 2011).

Since the invention of plastics in 1907, plastic use in commercial and domestic goods has risen to "near inexhaustible applications," with a plethora of societal benefits (Cole et al. 2011). Currently, 10% of waste is attributed to plastics (Wabnitz & Nichols 2010). However, 80% of worldwide pollution is plastic (Wabnitz & Nichols 2010). Of that, 80% of plastic pollution originates on land and ends up in the ocean (Cole et al. 2011). Plastics present in the marine environment can have substantial impacts; there are abundant studies describing the negative affect that plastics have on marine mammals, invertebrates, fish, and more (Laist 1997, Derraik 2002, Mrosovsky, Ryan, & James 2009, Wabnitz & Nichols 2010). In coral genera *Acropora.* and *Porites*, cleaning mechanisms and feeding interactions are affected by microplastic ingestion, decreasing the overall health of the coral reef (Reichert et al. 2017). Sea turtles and sea

birds have similar issues; plastic has been observed blocking the digestive tract of 37% of leatherback sea turtles analyzed since 1968 (Mrosovsky, Ryan, & James 2009). In an Arctic study from 2005-2014, 100% of little aulk seabirds were found to have microplastic in their GI tract (Amélineau et al. 2016). Ingestion is not the only risk for these vulnerable organisms; entanglement is common and can inhibit the functioning and survival of almost all species, most notably sea turtles and seabirds (Wabnitz & Nichols 2010). Plastics extensively pollute the environment, and this pollution reduces overall oceanic health and functioning. Unless this issue is addressed in a sustainable, meaningful way then the planet will face biodiversity losses, reduced ecosystem function, and more.

Table 1. Sources of common plastics (Thompson et al. 2004, Andrady 2011, Cole et al. 2011, Polymer Properties Database 2015, Peng et al. 2017, Mehta 2018).

Plastic Polymer	Polymer Abbreviation	Products/Origin
Low-density polyethylene	LDPE	Plastic bags, six-pack rings, bottles, netting, straws
High-density polyethylene	HDPE	Milk and juice jugs
Polypropylene	PP	Rope, bottle caps, netting, packaging, fishing gear
Polystyrene	PS	Packaging, plastic utensils, food containers
Polyethylene	PE	Packaging, fishing gear
Polyethylene Terephthalate	PET/Polyester	Packaging, air-blasting, clothing and textiles, glitter (nail polish, make up, hand sanitizer, paint, etc.)
Poly vinyl-chloride	PVC	Packaging, plastic film, bottles, cups
Foamed Polystyrene	Foamed PS	Fishing gear
Polyamide	Nylon	Fishing gear
Cellulose Acetate	CA	Cigarette filters, paperboard, plastic coated paper products
Melamine	N/A	Air-blasting, fibers in fire-blocking and high-risk textiles, airline seats, mattresses, protective clothing for firefighters, tire sealants
Rayon	N/A	Clothing, textiles, tire cords, hose, surgical materials, feminine hygiene products
Polyacrylates	PA	Coatings, paints, textiles, leather finishing, automotive products, tape adhesives
Alkyd	N/A	Paints, varnishes, enamels, printing inks, automotive refinishing, molding for electronics
Poly-vinyl alcohol	PVA	Textiles, paper strengtheners, fishing gear, coating for food, food packaging,
Polymethyl methacrylate	PMMA, Acrylic	Air-blasting, clothing and textiles
Polytetrafluoroethylene	PTFE/Teflon	Low-friction bearings, gears and slide plates, chemical resistant valves, filters and membranes, non-stick coatings for cookware and dyes, electrical insulators

Plastic polymers like PE, PS, PET, and PVC are typically found in packing products and may enter the ocean via beach litter and pollution. These polymers are more common as they are

used in high volumes, and plastic packaging is generally made to be disposable after a single use (Wabnitz & Nichols 2010, Andrady 2011). Another source of PE is microbeads in face washes, which enter the ocean by getting washed down the drain (Fendall & Sewell 2009). Polymers like foamed PS, PE, PP, and nylons are primarily used in fishing gear and enter the ocean when this gear is discarded or lost at sea; 18% of marine plastic debris is contributed to the fishing industry (Andrady 2011). Virgin, primary microplastic pellets are often lost during ocean transport or as run-off from processing facilities (Andrady 2011). Commercially, PMMA, melamine, and PET microbeads have been used in air-blasting technology, where air and plastics are blasted at machinery to remove paint or rust (Cole et al. 2011). PET, rayon, and PMMA are also the primary constituents of clothing (Peng et al. 2017). PE is also used to make rope, bottle caps, and netting. LDPE is used for plastic bags, six pack rings, bottles, netting, and drinking straws. PVC is used in plastic film, bottles, and cups. HDPE is used to produce milk and juice jugs (Andrady 2011).

Thompson et al. (2004) identified nine plastic polymers in estuarine and subtidal sediment samples, including alkyd, PE, PP, nylon, PET, PMMA, and PVA. The origins of these plastics were identified as clothing, packaging, and rope, and were therefore likely to be secondary microplastics that broke down from larger plastic waste. Peng et al. (2017) identified rayon, PET, and PMMA as the most abundant plastic polymers in sediments of the Changjiang Estuary in China. The primary source of these microplastics was laundry, indicating that laundry wastewater and drainage systems are the main contributor to the microplastic problem in that location (Peng et al. 2017). During classification of the plastics found, fibrous plastic made up 93% of the total plastics found (Peng et al. 2017). Dekiff et al. (2014) analyzed sediments in Norderney, an island off the North Sea coast of Germany. Overall, PP, PE, PET, PVC, PS, and nylon were found homogeneously among beach sediments, with no correlation to visible macro debris (Dekiff et al. 2014).

Morét-Ferguson et al. (2010) observed PE and PP in water samples collected via net tows between Cape Cod, MA and the Caribbean Sea between 1991 and 2007. In coastal Portuguese waters, 61% of zooplankton samples contained microplastics, primarily PE, PP, and PA (Frias et al. 2014). In Arctic polar waters, Lusher et al. (2015) found 665 plastic particles in 96 total surface and sub-surface samples. The plastics found were primarily CA/rayon, PET, and nylon

but also included PE, PMMA, and PVC (Lusher et al. 2015). Fibers were the most abundant plastic classification found (95%), and black and blue were the most abundant colors (45% and 29%, respectively) (Lusher et al. 2015).

As the scope of the microplastic pollution problem has become more apparent in recent years, a movement to ban microplastics has begun (Doughty & Eriksen 2014, Rochman et al. 2015). This resulted in bans in the UK (in 2018) and the US (in 2016) which specifically target microbeads, a form of primary plastic that can be made of PE, PP, nylon, PET, PMMA, or PTFE (Trager 2016, Vaughan 2016, Carrington 2018, McGrath 2018). Although these microplastics are now banned from face scrubs and washes, they are still allowed in several products such as lipstick, sunscreen, and paint (McGrath 2018).

To control the input of microplastics into the ocean and limit impacts caused by these microplastics, quantification of the most regularly occurring types and locations of plastics in the ocean is necessary to inform regulatory decisions. Despite bans that have been enacted to prevent microplastics from entering the ocean, there is still substantial evidence of plastic entering and accumulating in the ocean (Andrady 2011, Cole et al. 2011, Trager 2016, Lebreton et al. 2018, Carrington 2018, McGrath 2018). Profiling the presence and distribution of plastics in the water column will establish a baseline for future studies and support the development of thoughtful and effective mitigation strategies.

Of all ocean environments, coral reefs are often regarded as the most vital; reef ecosystems support total ocean productivity by providing habitat and resources for many marine species (Grandperrin 1978, Cole et al. 2008, Yao et al. 2013). Coral reefs also provide invaluable ecosystem services, including vibrant and healthy fisheries, coastal protection, and tourism (Hoegh-Guldberg et al. 2007). Scleractinian corals are the primary constituents of reef ecosystems, and are extremely productive and biologically diverse, improving general ocean health (Hoegh-Guldberg 1999). However, coral reefs are facing a broad array of threats, and coral disease has become widespread with rapid decrease in coral cover (Aronson & Precht 2001). Agriculture, deforestation, and development have led to eutrophication and degradation of habitat, and overfishing has decreased biological diversity and reduced population sizes of many fish species (Roberts et al. 2002). Destructive fishing methods (dynamite, poison) have become common, obliterating reef structure, habitat, and negatively impacting ocean health (Roberts et

al. 2002). Climate warming also poses a significant concern for reefs, as increasingly acidic oceans reduce coral growth rates, and bleached, unproductive corals become more common over time (Hoegh-Guldberg 1999, Roberts et al. 2002, Hoegh-Guldberg et al. 2007). Climate change may also give rise to more drastic natural disasters including hurricanes, floods, and heatwaves (van Aalst 2006). Hurricanes can break coral structures leading to declining reef health, with reduced coral cover observed in post-storm years (Scoffin 1993, Gardner et al. 2005).

One prominent, yet relatively unstudied threat to coral is microplastics. As corals are vital to both reef ecosystems and the ocean, the potential impact of microplastics on reef corals represents a tangible threat to marine life in general. Multiple studies have suggested that plastics are phagostimulants, driving ingestion in hard corals which in turn may lead to coral mortality from blockage of the digestive tract (Hall et al. 2015, Allen, Seymour, & Rittschof 2017, Reichert et al. 2017).

Microplastics are also vectors for heavy metals, contaminants, and chemicals (Brennecke et al. 2016, Hartmann et al. 2017). Brennecke et al. (2016) found that the lack of degradation of microplastic pollution in the water column enables accumulation of chemical contaminants such as heavy metals, which have a high affinity for microplastics. Microplastics have also been observed to concentrate hydrophobic organic chemicals, which may harm reefs and other marine biota (Cheng et al. 2010, Koelmans 2015, Hartmann et al. 2017). Microplastics and associated contaminants in the water column are therefore a significant potential risk to marine wildlife (Brennecke et al. 2016).

The Florida Reef Tract (FRT), a series of shore-parallel ridges and terraces, is a reef ecosystem supported by the warm waters of the Florida current (Banks et al. 2007). This tract extends from the Dry Tortugas through Martin County, FL, spanning 595 km of coastline, and is the third largest barrier reef ecosystem in the world (Figure 1) (Burman, Aronson, & van Woesik 2012, Walker & Gilliam 2013). The FRT is also home to over 65 coral species (including *Acropora cervicornis*, *Siderastrea siderea*, *Porites astreoides*, and many more), but is presently in crisis due to increased temperatures, disease, hurricanes, and more (Goldberg 1973, Precht & Miller 2007, Burman et al. 2012). This extensive reef system contributed $2.76 billion dollars to the Florida economy in 2012, with tourism being the largest contributor and fishing the second largest (Graham 2014).

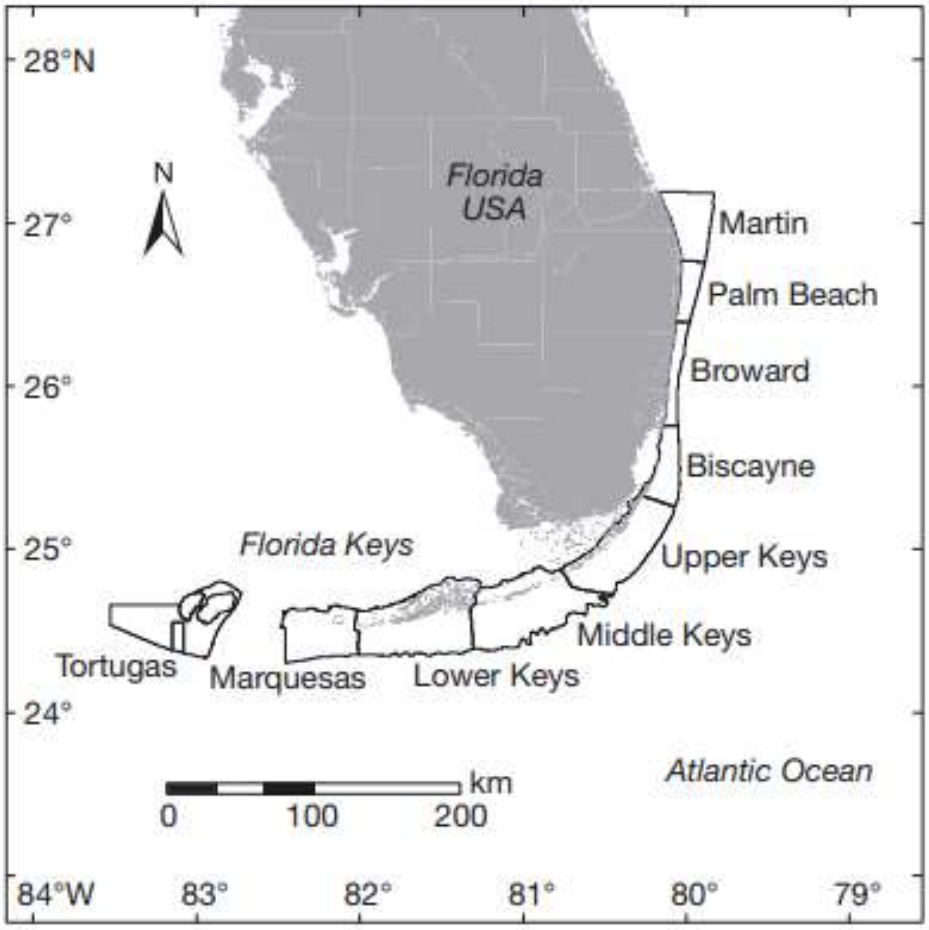

Figure 1. The span of the FRT, divided into county (Burman, Aronson, & van Woesik 2012). The northern portion of the FRT, from Martin County to Miami-Dade County, is the area referred to as the SEFRT.

The popularity of reefs can lead to overfishing, which is a major threat for two main reasons; the first, disruption of the food chain and thus general ecosystem functioning, and the second, plastic pollution that enters the ocean when fishing equipment is stranded (Precht & Miller 2007, Graham 2014). Overfishing is not the sole contributor to plastic pollution in the ocean, however. The SEFRT is the northern portion of the FRT, an area that is adjacent to several coastal population centers and "outfall" sites. At these outfall sites, partially treated sewage is dumped into the ocean (Van Velzer 2017). This sewage may include primary microplastics that are washed down the drain from facial scrubs, cosmetics, and cleaners as well as plastic fibers from laundry waste, and may also present a significant risk to the SEFRT (Fendall & Sewell 2009, Cole et al. 2011, Napper & Thompson 2016).

This study sought to address two main research questions: primarily, where can microplastic pollution be found along the SEFRT? And, based on this, can the observed pollution be classified, in terms of type of plastic? These questions give rise to three main hypotheses.

The first hypothesis is that microplastics will be found in equal quantities throughout the SEFRT. Outfall infrastructure exists near all inlets in Miami-Dade, Broward, and Palm Beach counties, although Boynton Inlet, Lake Worth Inlet, and Jupiter Inlet have policies in place to arrest dumping unless under "extreme circumstance" (Van Velzer 2017). Due to these closures, it is expected that microplastics will be found in lesser quantities in the area north of Boca Inlet. However, the role of the Gulf Stream and the Florida Current needs to be considered as well. Net water movement along the south Florida reef tract is north, which could allow microplastic accumulation on the northern end of the sampling locations as opposed to the southern end (Stommel 1965, Little 1977, Schmitz & Richardson 1991). Ultimately, it is expected that microplastics will be found in equal quantities throughout the sampling locations because of the balance of these two forces.

It is also hypothesized that microplastics will be observed in equal quantities in surface and bottom water samples. Sediment samples are typically indicative of the conditions of an ecosystem (Claessens et al. 2011). Benthic and demersal fauna as well as wave and current action agitate the sediment, allowing sediment components to reintegrate with the water column (Claessens et al. 2011). If plastics are present in a certain environment, they are likely to be observed most in bottom water. However, the two most common plastics are PP and PE, which both have densities less than that of seawater (0.92 g/cm^3, 0.95 g/cm^3, and 1.027 g/cm^3, respectively) (Andrady 2011, Reubold 2016). Thus, these abundant plastics will float to the surface if present in the water column (Reubold 2016). Due to these contradictory forces, it is anticipated that microplastics will be observed in equal quantities in surface and bottom samples.

The final hypothesis is that microplastics will be more abundant in the winter months, the later months of the study. Florida is a state indebted to tourism, drawing over 101 million tourists in 2019 alone (Turner 2018, VisitFlorida 2020). The high season in south Florida runs from November, when hurricane season is over, to April when temperatures begin to increase (Frommers 2020). This tourism may result in more populated beaches and increased output by outfall pumping stations, potentially increasing the amount of plastics entering the ocean. These

pumping stations disinfect the water before release, but do not have the ability to eliminate plastics from the flow before it enters the ocean (Tompkins 2015, Van Velzer 2017). Increased tourism in winter months may result in more microplastics being washed down the drain and more beach litter that could microcrack and cause further microplastic pollution. Thus, it is expected that microplastic abundance will be higher in winter months when tourism is greater.

There is a clear lack of information regarding the type and quantity of microplastics that occur along the SEFRT. A comprehensive analysis of water samples collected across a range of depths and locations will help to fill this data gap, improving future studies and the practical application of management strategies along the SEFRT.

METHODS

Sampling

Sampling took place at seven sites (Table 2, Figure 2) representing median locations between each inlet in Broward, Palm Beach, and Martin counties, and thus gave a complete and generalized incremental view of the whole SEFRT. Samples were collected monthly for a period of six months beginning in July 2019 in collaboration with the Coral Reef Restoration, Assessment, and Monitoring (CRRAM) lab water quality monitoring project at NSU, which is contracted via a grant from the Florida Department of Environmental Protection (FDEP).

Table 2. Site coordinates for each sampling location and corresponding site number from the water quality management project, where applicable. Sites were named for the inlet to the north. All sites are on the reef, with a bottom depth less than 18 meters.

Site	Site ID	Latitude	Longitude	Water Quality Management Site Number
South of Port Everglades	PEV	26 01.236	-80 06.714	PEV 046
Port Everglades to Hillsboro Inlet	HIL	26 09.598	-80 05.416	PEV 044
Hillsboro Inlet to Boca Raton Inlet	BOC	26 17.916	-80 04.480	BOC 075
Boca Raton Inlet to Boynton Inlet	BOY	26 24.990	-80 03.007	BOY 098
Boynton Inlet to Lake Worth Inlet	ILW	26 41.809	-80 01.819	ILW 118
Lake Worth Inlet to Jupiter Inlet	WPB	26 52.237	-80 02.349	N/A
North of Jupiter Inlet	JUP	26 59.691	-80 04.011	JUP 124

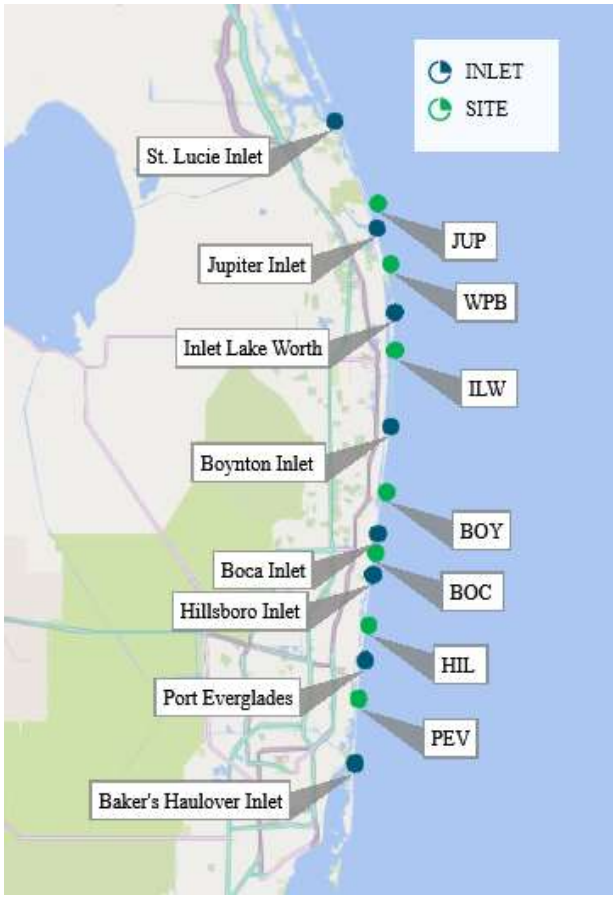

Figure 2. Map of sites along the SEFRT. Sample sites were placed approximately half-way between each inlet and coincided with a Water Quality Management site where possible. Sites were named for the inlet to the north of the site.

Bottom water samples were collected using a General Oceanics Niskin fired at the depth of the site, as described in both the NOAA National Oceanic Data Center and the FDEP/CRCP Florida Reef Tract Water Quality Management (WQM) protocols (FDEP/CRCP 2017, NOAA n.d., Whitall et al. 2019). The surface water samples were collected with a Nasco 12-foot-long swing sampler, 0.33m to 1m below the surface as described in the FDEP/CRCP Florida Reef Tract WQM protocol (FDEP/CRCP 2017, Whitall et al. 2019). Samples from each individual depth were condensed into separate buckets which were then used to fill six 1 L water samples each. Nova Southeastern University (NSU) boats were used for travel to and from sampling sites and sampling, in collaboration with the CRRAM lab and FDEP WQM project. Samples were

kept in a closed cooler without ice for no longer than one week, according to preservation and holding time guidelines outlined by RMB Environmental Laboratories (RMB 2019).

Sample Analysis

Two 1 L water samples, randomly selected from the six samples taken, were shaken manually for five minutes then vacuum filtered through a GF/A Whatman glass microfiber filter paper with a pore size of 1.6μm (Prata et al. 2019). A lab coat and gloves were worn to prevent contamination. Gloves were changed in between surface and bottom samples as well as before the blank and in between sampling sites. Equipment was triple rinsed with deionized water in between depths, the blank, and sites (FDEP/CRCP 2017, Whitall et al. 2019). These samples were dried in a fume hood for at least 12 hours, then analyzed and identified under a dissecting microscope set to 80x magnification (Ng & Obbard 2006, Andrady 2011). Plastics were identified under the microscope according to guidelines outlined by Hidalgo-Ruz et al. (2012) and compiled by the Marine & Environmental Research Institute (Marine & Environmental Research Institute n.d.). Examples of the microscopic appearance of microplastics shown in Figure 3. Recovered microplastics were manually counted and categorized into classification groups based on appearance and analyzed by Fourier Transform Infrared spectrophotometry (FTIR) at Eastfield College in Mesquite, TX (Thompson et al. 2004, Barnes et al. 2009, Andrady 2011). This protocol was repeated for all sample triplicates, at surface, bottom, and blank for all sites (Ng & Obbard 2006).

For July and August samples, plastics were picked off the filter and sent to the lab in 0.2 mL micro tubes, each tube representing a different identified classification group. Difficulties with this protocol arose after August samples were sent as the plastics were difficult to identify in the tubes. Samples from September through December were sent to the lab directly on the filter as to prevent loss of samples in transition, preparation, and transport. A clean filter was placed on top of the original filter then tin foil was wrapped tightly yet gently around the filters. The entire wrapped sample was placed back inside the petri dish and taped tightly for transport.

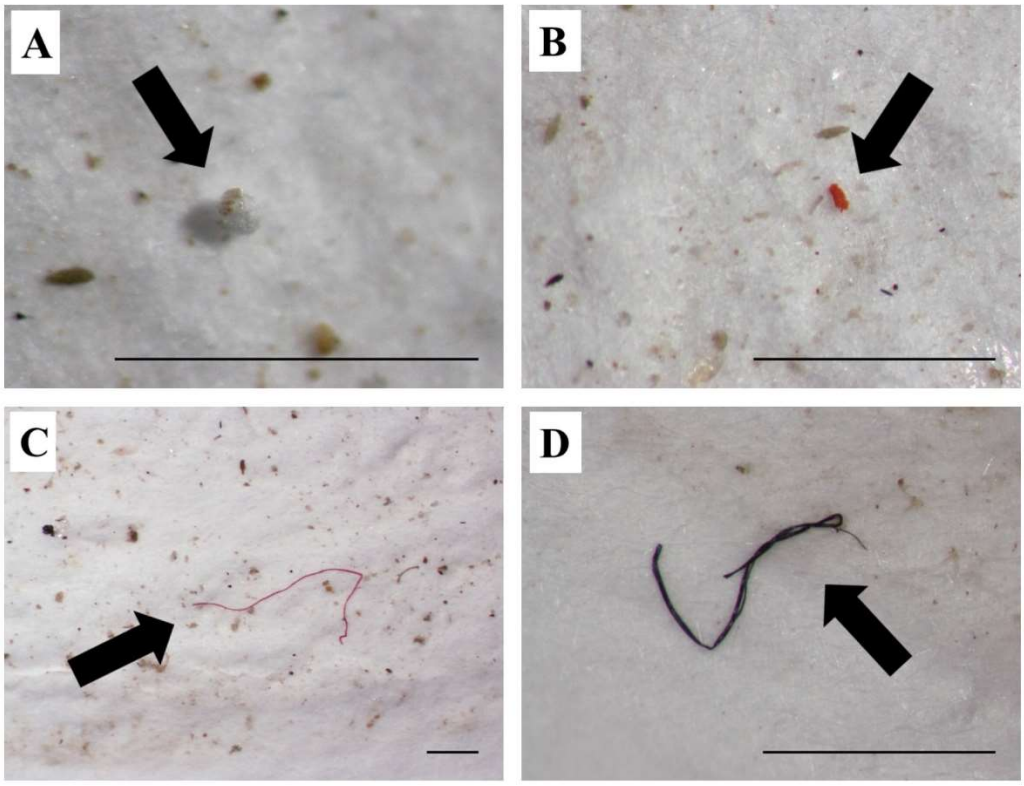

Figure 3. Microplastic fibers and pieces, as viewed under the dissecting microscope. A) white piece, B) orange piece**,** C) red fiber, D) black fiber. Scale bars: 2 cm. Plastics were identified according to guidelines outlined by Hidalgo-Ruz et al. (2012) and compiled by the Marine & Environmental Research Institute (Marine & Environmental Research Institute n.d.).

FTIR Analysis

For samples analyzed with the original protocol, approximately three drops of methanol were added to the microtube containing each sample with a small pipet and swirled to extract all plastic fragments. The methanol-plastic mixture was transferred to a slide and observed under a microscope to identify the sample. Once the plastic fragment was located, small forceps were used to lift the fragment and place it into the FTIR spectrophotometer. The sample was run by the FTIR spectrophotometer and results were tabulated from the resulting wavelength graph.

Samples that were analyzed with the second protocol were run slightly differently. Sample filters were carefully unwrapped, and the whole filter was placed under the microscope. The microplastic sample was located using reference photographs, and small forceps were used to place samples into the FTIR spectrophotometer. Again, the sample was run by the FTIR spectrophotometer and results were tabulated from the resulting wavelength graph. Great care

was taken to ensure that no filter fragments were included in the sample placement and subsequent analysis. The FTIR spectrophotometer was calibrated at least once per month with additional calibrations performed if deemed necessary.

Data Analysis

To test the hypothesis that microplastics would be found in equal quantities along the SEFRT, a two-tailed t-test (α=0.05) was used to compare plastic quantities at southern sites with active outfall pumping to northern sites where no such infrastructure exists. Sites were grouped based on outfall status, active or inactive. Data were found to be homoscedastic (Bartlett test, α=0.05) and normally distributed (Shapiro-Wilke test, α=0.05). This test allowed for comparison of northern and southern sites in order to determine if latitude affected plastic quantity.

To test the hypothesis that microplastics would be found in equal quantities in surface and bottom samples, a two-tailed t-test (α=0.05) was used. Data was found to be homoscedastic (Bartlett test, α=0.05) and normally distributed (Shapiro-Wilke test, α=0.05). This test allowed comparison of plastic quantities in surface water samples to those in bottom water samples.

Descriptive statistics were used to evaluate pollution composition and frequency, abundance of polymers, and descriptions of plastic quantities along the SEFRT at all depths over time (Gotelli & Colwell 2001). Pollution composition, determined by FTIR analysis, addressed the second research question regarding if pollution can be classified and allowed for the calculation of the percent composition of each species of microplastic. Once percentages were determined, conclusions were drawn regarding which plastic species appeared the most frequently across all samples, permitting a more thorough and comprehensive look into the pollutant makeup of each individual site and the way each factor impacted the total. This also allowed assessment of the relative contribution of different plastic types to microplastic pollution. Based on the patterns revealed, conclusions were then drawn regarding the final hypothesis that PP would observed more than any other type of plastic.

To address the main research question regarding where microplastic pollution can be found along the SEFRT, the amount of microplastics between locations, between depths, and between collection month was compared. Data failed to meet the assumptions of analysis of variance (ANOVA) even after scale transformations, so a Kruskal-Wallis Rank Sum test

(α=0.05) was performed in place of a fixed factorial ANOVA. This test allowed insight into differences in microplastic abundance between specific locations and depths (Thompson et al. 2004, Ng & Obbard 2006, Ballent et al. 2016).

RESULTS

All in all, no significant differences in plastic quantity existed between depths, locations, or months combined, supporting the hypothesis that microplastics would be found in equal quantities throughout the SEFRT.

Geographic Influence

There was no site where microplastics were consistently found in greater quantities than another. The least amount of plastics were found at ILW in August (4) (Figure 4). By contrast, the greatest amount of plastics were found at BOC in the same month, August (98). BOC overall displayed the most plastics (231) and the least total plastics occurred at PEV (83) (Figure 4). The remainder of the locations had total plastic abundances between 124 and 201. The least amount of polymers were found in BOY in August, when only two polymers were found. The most polymers were found in JUP in August, WPB in September, and WPB in December.

Influence of the Outfalls

No significant difference existed between outfall sites and non-outfall sites (Two-tailed T-test, $p = 0.8852$). A mean (±SE) of 150.67 (±43.19) plastics were found per outfall site, with a mean of 75.33 (±43.19) per month found at all outfall sites combined. At non-outfall sites a mean of 158 (±15.96) plastics were found per site, with a mean of 105.33 (±15.96) per month (Figure 5).

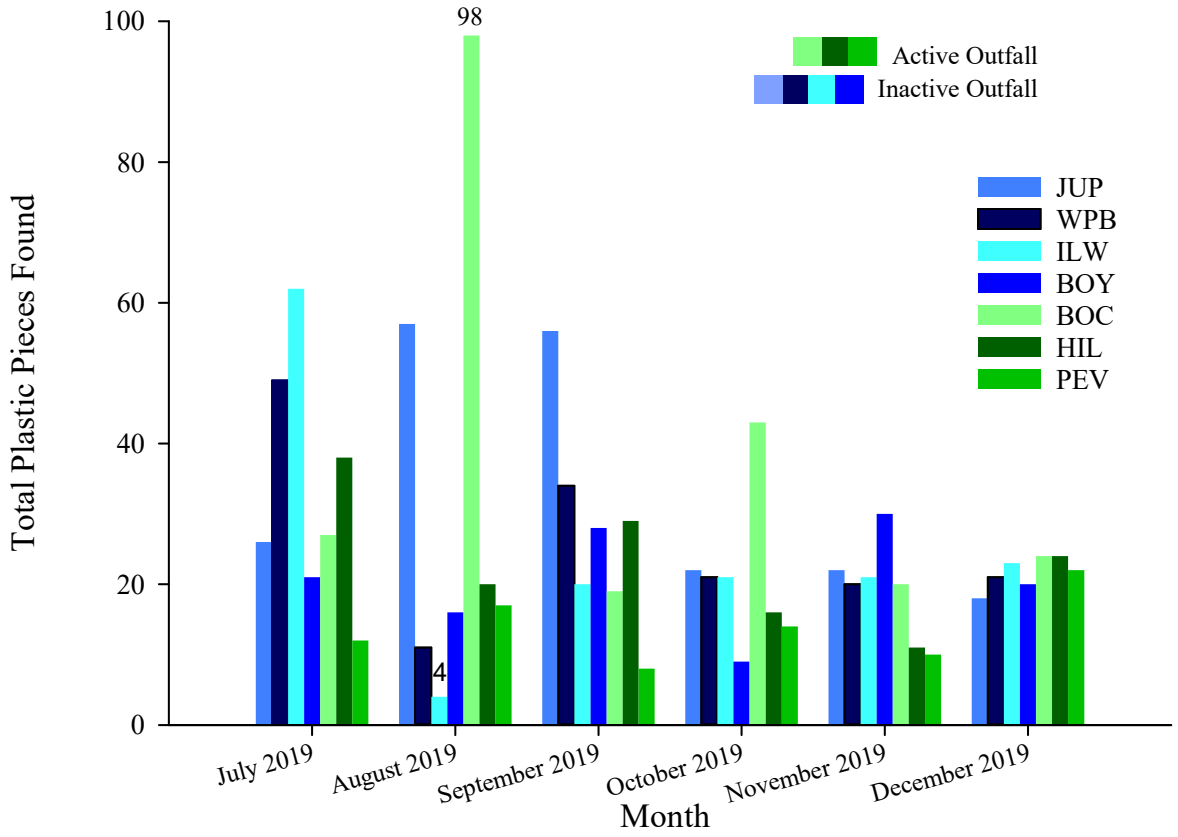

Figure 4. Total microplastic abundance per month, broken up by site and identified via outfall activity. These numbers indicate the total plastic pieces identified at each site during each month.

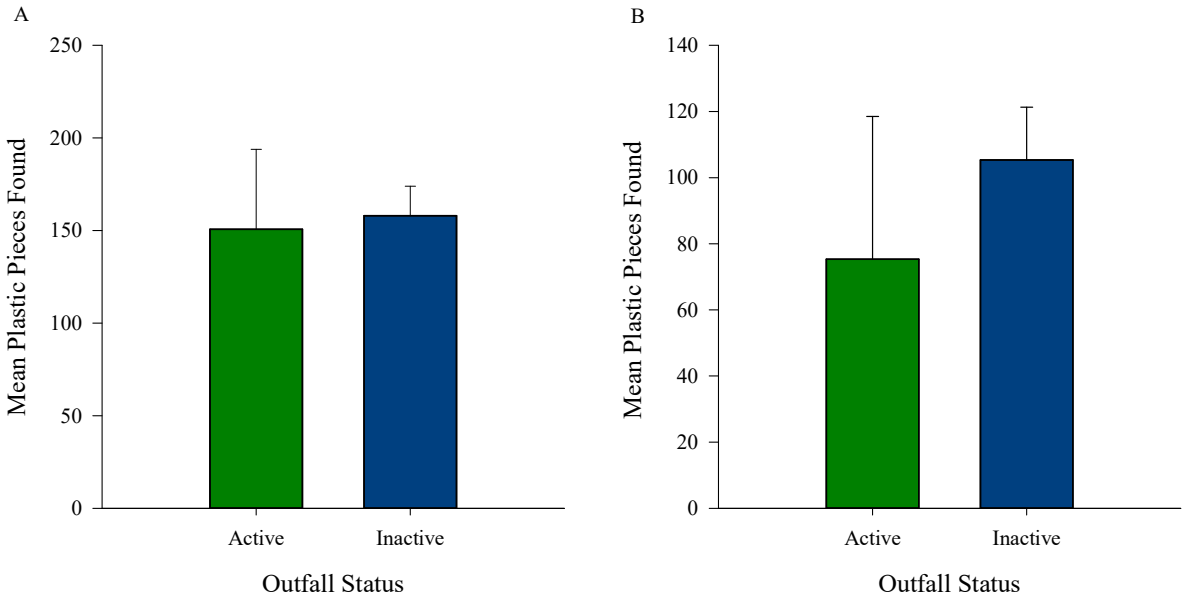

Figure 5. A) Mean plastics (±SE) at surface and bottom found per site, pooled based on outfall status. B) Mean plastics (±SE) found per month at all sites and depths, pooled based on outfall status.

Role of Depth

A significant difference was found between mean plastic abundance in surface and bottom samples (Two-tailed T-test, p = 0.01956). Surface water samples displayed a significantly higher quantity of microplastics than bottom water samples; this trend was consistent month after month (Figure 6). A total of 686 plastics were found from all surface sites, compared to a total of 398 plastics found from all bottom sites. A mean (±SE) of 114.33 (±14.48) plastics were found in surface samples; a mean of 66.33 (±6.67) plastics were found in bottom samples (Figure 6). In July, there were 53 more plastics found in surface samples than in bottom samples. In August, that difference increased more than two-fold. After that, plastics found in surface samples slowly decreased while plastics found in bottom samples slowly increased (except for in September, in which plastics in bottom samples jumped rapidly only to decrease again in October). By December, plastic quantities in surface and bottom samples differed only by 10.

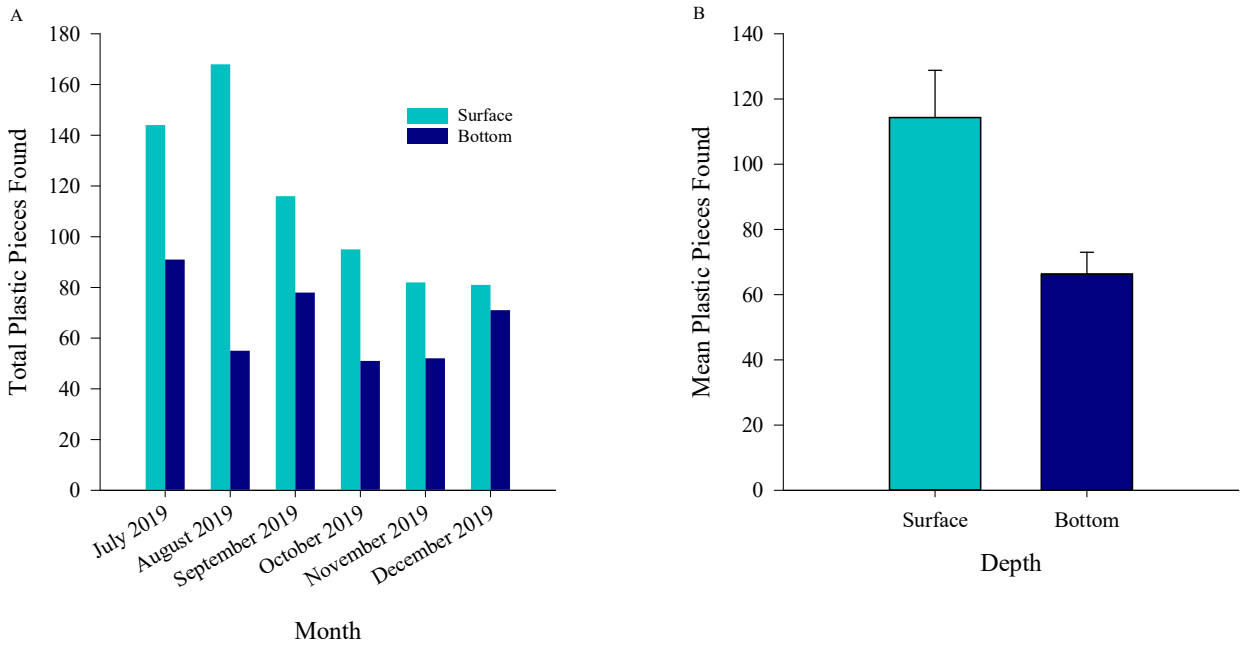

Figure 6. A) Total microplastics found at surface and bottom sites each month. B) Mean (±SE) plastics found at surface and bottom sites across all sites and all months.

Microplastic Classification

A total of 1,204 individual microplastic fragments were found over the course of this study, represented by 20 plastic classifications (blue fiber, clear fiber, shiny bead, white fiber, amber fiber, red fiber, green fiber, black fiber, dark green fiber, unidentified cluster, blue piece, orange fiber, brown fiber, light blue fiber, white cluster, clear shard, white piece, dark blue piece, dark blue fiber, and red piece). Of these, 86.8% (1142 pieces) of plastics found were identified as fibers. The remaining 13.2% (159 pieces) were identified as clusters, shards, or pieces. A total of 115 microplastics were found in blank samples, accounting for 9.5% of the total plastics found.

The most commonly occurring classification was blue fiber (466 pieces, 38.7%), followed by black fiber (277 pieces, 23%). The least commonly occurring polymer was dark blue piece, occurring only once over the six-month study (1 piece, 0.08%). Red piece and dark green fiber each occurred only twice (0.17%, each).

The most common color identified was blue (607 pieces, 50.4%). This number included BF, BP, LBF, DBP, and DBF which all had a blue element to them; of these classifications, BF is responsible for 76.8% of blue plastics found. Blue abundance was followed by black, then clear/white, green, red, amber, brown, and finally orange (Table 3). Only 4 pieces, 0.3%, were unspecified in color.

Table 3. Color categories, their associated classifications and total pieces found. For classification group definitions, see Table 4.

Color	Classification Category Considered	Number of Pieces Found	Percentage of total
Blue	BF, BP, LBF, DBP, DBF	607	50.42%
Black	BLF	277	23.01%
Clear/White	CF, SB, WF, WC, CS, WP	131	10.88%
Green	GF, DGF	104	8.64%
Red	RF, RP	51	4.24%
Amber	AF	16	1.33%
Brown	BRF	8	0.66%
Orange	OF	6	0.5%
Unspecified	UC	4	0.33%

Plastic Polymers

Of the samples that were sent for FTIR analysis, 7 polymers were successfully identified; rayon, PE, and PP were each found only once in all FTIR analyzed samples; CA was found 42 times; cellophane 8 was observed 12 times, cellophane 40 was found 46 times, and vinyl alcohol/vinyl butyral 70 times. There were 24 individual samples identified only as organic, non-plastic material. Chemical, non-plastic identifications included gun powder, which occurred 6 times, trimethoxyamphetamine which occurred 5 times, 1,2 diiodoethane, which occurred 4 times, and methyl vinyl sulfone and octane which each occurred only once.

There were three classification groups that were not identified as a plastic polymer at least once during FTIR analysis, but only one of these classification groups, green piece, was observed only once during filter analysis and could be ruled out entirely as a plastic polymer. 91.7% of non-plastic identifications were made before protocol alteration took place after August, and all 7 lost samples occurred before this protocol change as well. The only plastic polymers that were discovered post-protocol change were vinyl alcohol/vinyl butyral and rayon.

Table 4. Polymer and organic identifications, as well as frequency of identification. Both polymer and organic identifications are organized from most identified to least identified. Identified classification groups are explained in the first column and their abbreviations are given in the second column. Classifications that were more commonly observed are listed first, decreasing from top to bottom.

Identification/ Appearance Category	Abbreviation	Polymer (positive identifications, percent of total identifications)	Organic (positive identifications, percent of total identifications)	Total Pieces Found	Percentage of Total
Blue fiber	BF	Vinyl alcohol/vinyl butyral (20, 27%), cellophane 40 (18, 25%), CA (18, 25%, cellophane 8 (5, 7%)	Gun powder (3, 4%), trimethoxyamphetamine (2, 3%), methyl vinyl sulfone (1, 2%), 1,2 diiodoethane (1, 2%), 4 naturally occurring organic identifications	466	38.67%
Black fiber	BLF	Cellophane 40 (7, 28%), CA (6, 24%), vinyl alcohol/vinyl butyral (4, 16%), rayon (1, 4%)	Trimethoxyamphetamine (1, 4%), 6 naturally occurring organic identifications	277	22.99%
Blue piece	BP	Vinyl alcohol/vinyl butyral (16, 66%), cellophane 40 (2, 8.3%), CA (2, 8.3%)	4 naturally occurring organic identifications	97	8.05%
Green fiber	GF	Vinyl alcohol/vinyl butyral (7, 50%), cellophane 40 (2, 14%), cellophane 8 (1, 7%), CA (1, 7%)	2 naturally occurring organic identifications	95	7.88%

Table 4. Polymer and organic identifications (continued)

Identification/ Appearance Category	Abbreviation	Polymer (positive identifications, percent of total identifications)	Organic (positive identifications, percent of total identifications)	Total Pieces Found	Percentage of Total
Clear fiber	CF	Vinyl alcohol/vinyl butyral (5, 22%), cellophane 40 (4, 17%), CA (3, 13%), PE (1, 4%), PP (1, 4%), cellophane 8 (1, 4%)	Octane (1, 4%), 7 naturally occurring organic identifications	62	5.15%
Red fiber	RF	Vinyl alcohol/vinyl butyral (4, 31%), cellophane 40 (3, 23%), CA (3, 23%)	Trimethoxyamphetamine (1,8%), 2 naturally occurring organic identifications	49	4.07%
Shiny bead	SB	Vinyl alcohol/vinyl butyral (2, 40%), cellophane 40 (1, 20%), CA (1, 20%)	1 naturally occurring organic identification	30	2.49%
Light blue fiber	LBF	Vinyl alcohol/vinyl butyral (4, 100%)	N/A	25	2.07%
Dark blue fiber	DBF	N/A	1,2 diiodoethane (1, 100%)	18	1.49%
Amber fiber	AF	Cellophane 40 (3, 38%), CA (3, 38%), cellophane 8 (1, 13%)	1 naturally occurring organic identification	16	1.33%
White cluster	WC	Vinyl alcohol/vinyl butyral (1, 100%)	N/A	16	1.33%
White fiber	WF	Cellophane 40 (3, 38%), CA (3, 38%)	Gun powder (2, 25%)	14	1.16%
Dark green fiber	DGF	Vinyl alcohol/vinyl butyral (2, 50%)	Gun powder (1, 25%), 1 naturally occurring organic identification	9	0.75%
Brown fiber	BRF	Vinyl alcohol/vinyl butyral (4, 100%)	N/A	8	0.66%
White piece	WP	Vinyl alcohol/vinyl butyral (1, 50%)	Trimethoxyamphetamine (1, 50%)	7	0.58%
Orange fiber	OF	Vinyl alcohol/vinyl butyral (2, 66%)	1 naturally occurring organic identification	6	0.50%
Unidentified cluster	UC	Cellophane 40 (4, 44%), cellophane 8 (3, 33%), CA (1, 11%), vinyl alcohol/vinyl butyral (1, 11%)	N/A	4	0.33%
Clear shard	CS	No data	No data	2	0.17%
Red piece	RP	No data	1,2 diiodoethane (1, 100%)	2	0.17%
Dark blue piece	DBP	Vinyl alcohol/vinyl butyral (1, 100%)	N/A	1	0.08%

Monthly Variation

From month to month, percentage of classifications found varied, but BLF and BF were consistently the highest percentage of classifications found. The ratios of classifications found per month are shown in Figure 7. The only classifications consistently found across all six

months were BF, CF, RF, GF, BLF, and BP. There were no months in which no plastics were found.

The widest variety of classifications were discovered in November and December- 13 different classifications were observed in each month, compared to 12 in August and September and 11 in July and October. There was an average of 6±1.67 different types of classifications found per site per month. Total plastics found per site were more uniform in the later, winter months of the study; among sites, there was more variation in total pieces found in July-October. Plastics found were more homogenous from site to site in November.

Total microplastic pieces found decreased every month until December, when plastic abundance was slightly higher than November (Figures 7 and 8). The greatest number of microplastics were found in July (269), with only 155 found in November, a decrease of 57.62%.

No significant difference was found between depths, locations, or months combined (Kruskal- Wallis Rank-Sum, p= 0.4794).

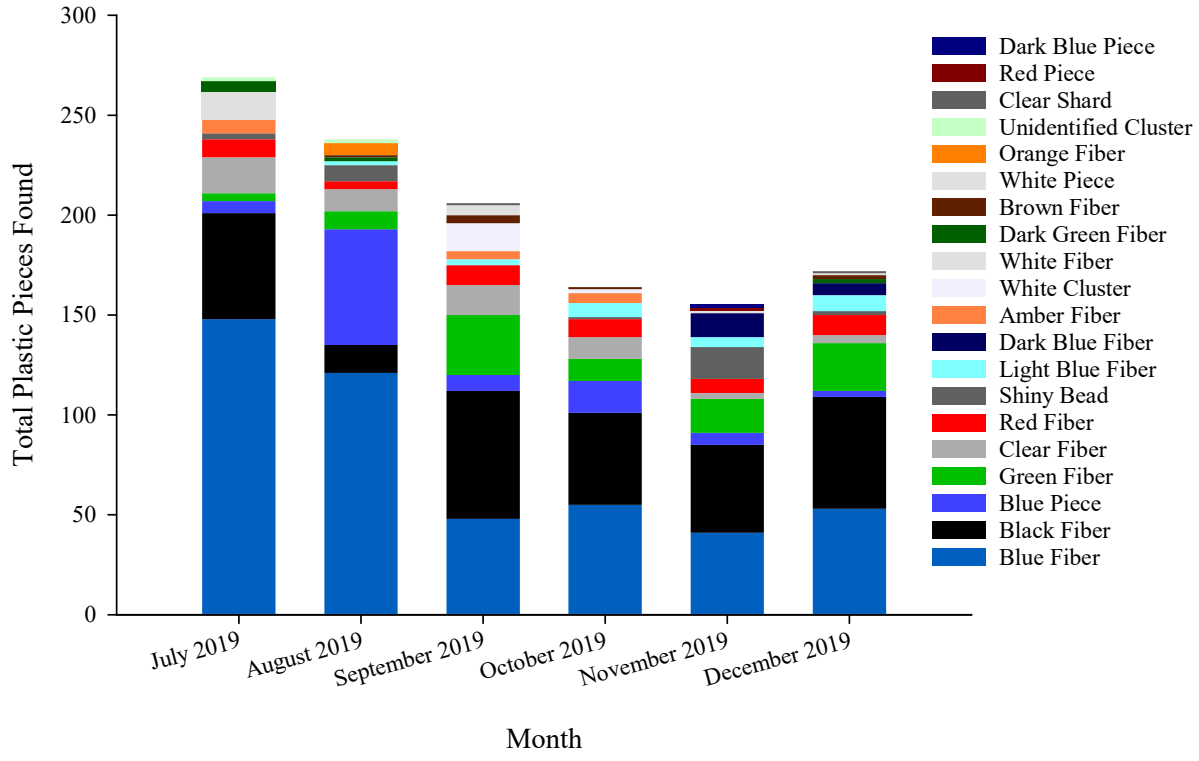

Figure 7. Total plastic pieces found over time, by classification group. Segment color corresponds to color of the classification group. Classification group abbreviations can be explained in Table 4.

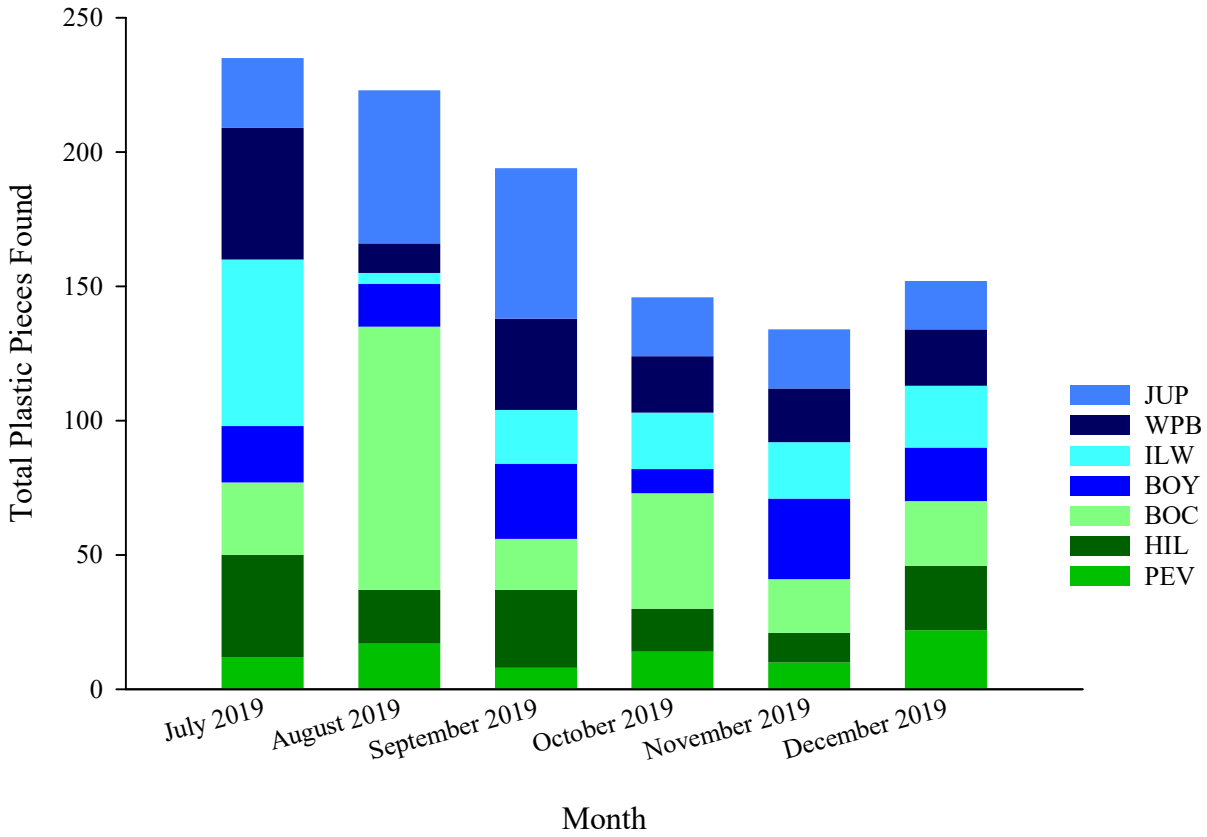

Figure 8. Total plastic pieces found over time, by site (not including blanks). Colors correspond to outfall status, as in Figures 4 and 5; green represents sites with active outfall pumping, while blue represents sites with no pumping. Southern sites are represented at the bottom of the graph while northern sites are represented towards the top. Abbreviations of sites are explained in Table 2 and Figure 2.

Absence of Microplastics

There were only 17 total samples in which no plastics were found; of these, 10 were bottom samples and 5 were surface samples (Figure 9). Every month besides December yielded at least one site in which no plastics were found. In July, only one sample contained no plastics. August displayed the most samples with no plastics: 7, compared to 3 each in September, October, and November (Figure 9). Two of the samples that displayed no plastics were blank samples. Excluding blank samples, ILW and HIL each had 4 samples with no plastics. There were no JUP samples that contained no microplastics (Figure 9).

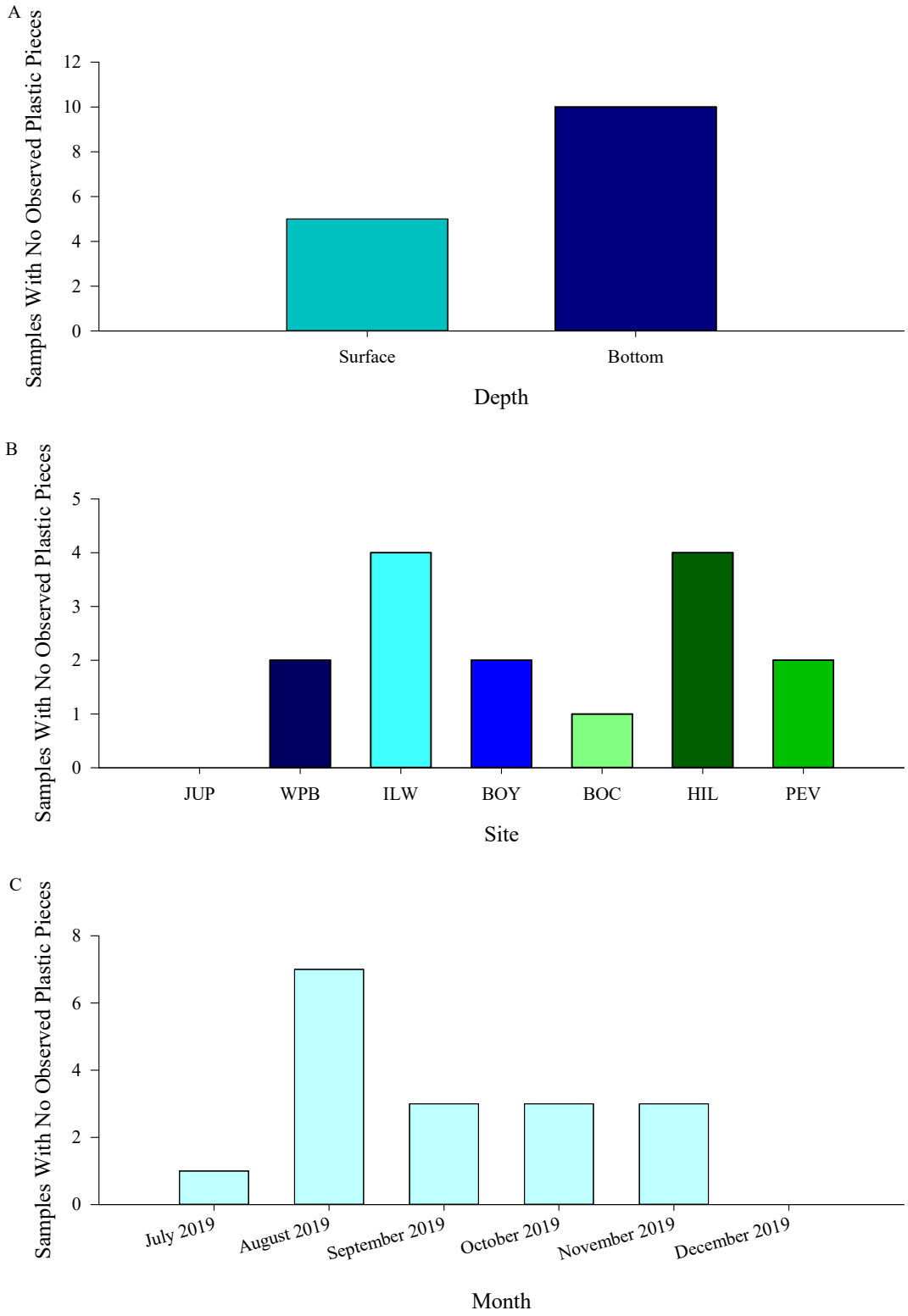

Figure 9. A) Total samples in which no plastic pieces were found, based on sample depth B) Total samples in which no plastic pieces were found, based on site. Site abbreviations are explained in Table 2 and Figure 2 C) Total samples in which no plastic pieces were found, based on month.

DISCUSSION

The goal of this study was to analyze microplastic quantities and composition at different depths and latitudes along the SEFRT, in order to better understand the current state of microplastic pollution in south Florida and assess the possible pathways in which these plastics enter the ocean. This was the first study analyzing microplastic quantity and composition along the SEFRT. Plastic was found multiple times at every site, depth, and month in which samples were collected, with 1,204 plastic pieces found in total. Seven polymers were successfully identified within 20 classification groups, and fibers and pieces were identified in nine color categories.

Geographic Influence and the Influence of the Outfalls

The greatest overall microplastic quantities were observed at site BOC. This site is the northernmost active outfall site, so it is possible that these microplastics were introduced into the ocean via all outfall sites to the south and plastics congregated at BOC via northward water movement of the Gulf Stream and the Florida Current (Stommel 1965, Little 1977, Schmitz & Richardson 1991, Fendall & Sewell 2009, Cole et al. 2011, Napper & Thompson 2016). Further north, these plastics could have been more evenly distributed due to reintegration of plastics in the water column. This northern water movement might also explain polymer discrepancies from site to site. The most northern sites, JUP and WPB, displayed the highest number of plastic classifications found. It is likely that plastics entering the ocean from the south flowed northward, leading to a greater variety of plastics in the northernmost sites.

It was unexpected that the least amount of microplastics were found offshore of Port Everglades, one of the busiest cruise ship and cargo ports in the country (Stamates et al. 2013). It is expected that one of the busiest ports would contribute to ocean plastic via lost or abandoned fishing debris, microcracking of larger plastics discarded on busy beaches, or as a result of a dense population disposing of plastics in wastewater. It was also unexpected that no significant difference in plastic quantities was found between outfall sites and sites with no active outfalls.

These results may be explained by two main concepts. First, it is possible that plastic pollution entered the ocean in equal quantities from the outfalls and from microcracking and embrittlement of larger plastics such as fishing waste or beach debris. Second, the large amount

of water movement along the SE Florida coast likely homogenized plastics in the water. The coast that runs parallel to the SEFRT is known as a "coastal mixing zone," an area of large water mixing (Maliva et al. 2001, Melim, Swart, & Eberli 2004). This large water movement is likely the driving factor of these relatively homogenous plastic quantities, regardless of the source or entry point of the microplastics.

Role of Depth

The quantities of plastics in surface samples was significantly higher than the quantities of plastics in bottom samples. The two most common plastic polymers, PE and PP, both have densities less than that of seawater (Andrady 2011, Reubold 2016). Since the most commonly occurring plastics overall are also those that are lower density than seawater, it is feasible that this would result in greater microplastic abundance in surface samples.

However, the most commonly occurring plastic in this study was vinyl alcohol/vinyl butyral, which has a density between 1.07 g/cm^3 and 1.33 g/cm^3, which is greater than the density of seawater (1.027 g/cm^3). It would thus be expected that these plastics would sink, and therefore be found more commonly in bottom water (Polymer Properties Database 2015, Reubold 2016). This may be explained by the possibility that these plastics recently entered the ocean near the surface and had only just begun their slow descent through the water column. Another possible explanation is that foraging and other anti-fouling mechanisms have decreased the density of these plastic particles, and they are now buoyant enough to reside in surface waters (Andrady 2011).

The fouling and anti-fouling cycle may explain the gradual homogenization of plastic quantities between surface and bottom samples over the course of the study. When plastics enter the ocean, they become fouled with debris and sink to the benthos, but as foraging and other anti-fouling processes take over, the plastics will float to the surface (Andrady 2011). Fouling begins rather rapidly after the insertion of plastic particles into the ocean and because this pattern is cyclical, the introduction time of the plastic pollution cannot be determined (Andrady 2011). However, this process could explain the difference in plastic abundance between surface and bottom samples; plastics input into the surface waters may have been in the fouling phase of this cycle, sinking over the course of the study to the benthos.

The larger amount of microplastics in surface samples may also be due to processes in the surface ocean. The sea-surface microlayer, a layer of atmospheric and oceanic transfer on the sea surface, has been proven to be an assemblage zone of anthropogenic materials (Hardy 1982). It is possible that microplastics in the ocean are congregated in this surface microlayer. This idea is supported by nutrient trends revealed in the FDEP/CRCP WQM study; silica, orthophosphate, total nitrogen, nitrite, nitrate, and ammonium were all significantly higher in surface samples than bottom samples (Whitall et al. 2019). This reinforces the concept that nutrients, plastics, and more may accumulate in the sea-surface microlayer.

Sargassum windrows are another possible congregator of microplastics in the surface ocean. Microplastics have been observed associated with macroalgae and seagrasses (Seng et al. 2020). *Sargassum* is a genus of macroalgal seaweed known for the many "bladders" that keep the seaweed generally buoyant and is common in sub-tropical and tropical waters like that off the coast of south Florida (Prince & O'Neal 1979, Niermann 1986). Thus, this *Sargussum* may act as a vector for microplastics, allowing their increased presence in surface waters.

Microplastic Classification

Fibers were the predominant microplastic type found, in a range of colors. Fibers typically enter the ocean from laundry wastewater and possibly occur due to degradation of fishing line. The overwhelming presence of these fibers indicated that much of the microplastic pollution in the ocean along the SEFRT originates as laundry wastewater at outfall sites, with a minority contributed by the degradation of fishing line. The presence of more fibers than pieces is consistent with previous studies (Thompson et al. 2004).

The most commonly occurring classification group was blue fibers, and the most common identification of blue fibers was vinyl alcohol/ vinyl butyral. The second most commonly occurring classification group was black fibers, and the most common identification for this classification was cellophane 40. Both of these plastics are typically used for commercial purposes like adhesives and packaging, indicating that the source of these plastics was likely microcracking from larger plastics. However, the fact that each are fibers and not pieces indicates that it is possible these fibers came from textiles, washed into the ocean via the outfalls.

Plastic Polymers

A majority of plastics observed in collected samples likely entered the ocean through microcracking from larger plastic items; vinyl alcohol/vinyl butyral, cellophane 40 & 8, CA, and PE are all typically used in production of larger plastic or for use in commercial settings, and likely enter the ocean as secondary microplastics that have broken down from larger plastics. (Table 5). PP has uses that would allow them to enter the ocean either as primary or secondary microplastics (Table 5). Rayon is primarily used in textiles, and likely enters the ocean as a primary microplastic (Table 5).

Table 5. Identified polymers, the typical source of these plastics, and the likely form of the plastic upon entry to the ocean (Cascone et al. 2001, Rogers 2015, Creative Mechanisms 2016).

Polymer	Source	Likely Form Upon Ocean Entry
Vinyl alcohol/vinyl butyral	Laminate or adhesive in glass, food and can coatings, commercial adhesive	Secondary
Cellophane 40 & 8	Food packaging	Secondary
CA	Plastic-coated paper products, cigarette filters	Secondary
PE	Packaging or manufacturing of heavy-duty plastic products	Secondary
PP	Consumer products, automotive manufacturing, textiles	Primary or secondary
Rayon	Textiles	Primary

Chemicals and other non-plastic substances were also discovered in the samples. These identifications included gun powder, trimethoxyamphetamine, 1,2 diiodoethane, methyl vinyl sulfone, and octane. The presence of these non-plastic, chemical components alongside plastic pieces and fibers indicates that plastics may act as a congregator of harmful contaminants (Table 4). There is ample evidence for this idea, as microplastics have been proven to be vectors to heavy metals, contaminants, and chemicals (Brennecke et al. 2016, Hartmann et al. 2017). When these chemicals and contaminants are concentrated in the water column, this may increase the risk to marine wildlife, harming reefs and other marine biota (Cheng et al. 2010, Koelmans 2015, Brennecke et al. 2016, Hartmann et al. 2017).

Trimethoxyamphetamines are a class of chemical hallucinogenic drug (Uyeno, Otis, & Mitoma 1968). It is known that these drugs may cause hallucinations, physical and mental health risks, and "performance interruptions" in humans, rats, and squirrel monkeys (Uyeno, Otis, & Mitoma 1968, Zaitsu et al. 2007, Nagai, Nonaka, & Kamimura 2007). 1,2 diiodoethane may cause skin, eye, and respiratory irritation in humans (PubChem 2020). Methyl vinyl sulfone is a combustible, highly toxic, and poisonous irritant that can emit toxic fumes during decomposition and create hydrogen gas (NOAA 2020). Octane is flammable, a strong irritant, and potential fatal to humans if swallowed. It has also been proven to be very toxic to aquatic life (PubChem 2020). Gun powder has also been proven to be hazardous and toxic to the aquatic environment with long lasting effects (Alliant Powder 2012). The singular and cumulative effects of these chemicals on marine biota has not been extensively studied, and thus their impact on the ocean is unknown (PubChem 2020).

Monthly Variation

Over the course of this study, total microplastic abundance was greatest in July and decreased steadily over time with only a slight increase in December. There were no individual locations that displayed larger microplastic abundance in the high season of the winter months. The hypothesis that more microplastics would be found in winter months was therefore not supported. It is likely that a combination of climate trends, weather patterns, and tourism patterns effect monthly microplastic abundance across the SEFRT.

The convergence of microplastic quantities over time is possibly related to climate trends. Wind and wave data collected at each site during this study supports the idea that severe weather in the winter months is likely the cause of homogeneity in microplastic quantity between surface and bottom samples. In July, August, and September, average wind speed was typically between 5-10 knots and usually had a western component, which prevent the formation of offshore waves. However, in October, November, and December wave height and wind speeds increased, and wind direction more often contained an easterly component, allowing for waves to build offshore. It is likely that this increased wave action resuspended settled microplastics and promoted mixing of the water column, thus homogenizing the distribution of microplastics between surface and bottom samples. While no hurricanes directly impacted south Florida in 2019, there were 2 tropical cyclones and one hurricane that passed or built reasonably close to

Florida in the North Atlantic Ocean between July and December; one each in August, September, and October. (NOAA 2020). It is likely that these storms impacted the distribution of these microplastics, possibly helping to explain the greater variation in microplastic quantities between depths and sites in the earlier months of the study.

The decrease in plastic quantity over time may also be attributed to rainfall trends in south Florida. An average of 60% of the yearly rainfall in south Florida falls between June and September (Duever et al. 1994). The average rainfall in July, August, and September across Martin, Palm Beach, Broward, and Miami-Dade counties was 6.64 inches, compared to 4.68 inches in October, November, and December in the same area (SFWMD 2020). This supports the idea that large rainfall events resulted in greater amounts of plastics in runoff and contributed to excess pumping of outfalls; this was reflected in the higher quantity of microplastics discovered in the summer months than the winter months.

Historical tourism trends reveal that tourism is typically even throughout the year. While data for 2019 is not fully available, Visit Florida reports a difference of only 0.82 million visitors between July-September 2018 and October-December 2018, and a difference of only 5.33 million visitors year-long (VisitFlorida 2020); in 2018, tourism was higher in July-September (31.26 million visitors) than in October-December (29.44 million visitors) (VisitFlorida 2020). This increased tourism in the summer is likely the cause of increased microplastic abundance in the summer months, as a larger population could result in more plastics entering the drain and more plastic debris being washed into drainage systems and thus, the ocean. Population drives consumption, so an increased population will result in larger plastic consumption and improper disposal could mean more plastics entering the ocean. The slight increase in microplastic abundance in December indicates a possible lag in the time from when tourism increased and the plastic appeared in the ocean. High plastic abundance in summer months could also be correlated with the public-school calendar; as more kids were out of school in the summer, it is possible that more plastic entered the oceans via recreational activities such as diving, snorkeling, fishing, and bathing.

CONCLUSION

This study has provided valuable information about the state of microplastic pollution in the ocean in south Florida, and revealed patterns regarding both microplastic abundance and related chemical abundance over a six month period. Prior to this study, temporal, latitudinal, and depth-dependent microplastic trends along the SEFRT were uncharacterized. Microplastics pose threats to marine life through their very existence, but also threaten aquatic biota as vectors of harmful contaminants. This study has revealed that microplastic pollution, and all threats that this pollution presents, is abundant throughout the SEFRT.

Plastic is likely to accumulate with no disposal strategies in place, and it is very likely that the accumulation of this plastic pollution will impact sea life and thus, human life. A multi-faceted approach is needed to halt the input of microplastics into the ocean; including bans on unnecessary plastics, and stricter laws and controls in coastal cities concerning litter from beachgoers and fishermen.

A full understanding of the scope of the microplastic problem along the SEFRT requires the analysis of long-term trends, which are key in analyzing the impact of microplastic on the oceanic environment. Subsequent studies should therefore incorporate long-term monitoring plans and a broader sampling scope. Sediment samples would be very useful in this regard, as it is possible that denser plastic particles are buried in the sediment, and sediment samples may allow for a more complete understanding of microplastic pollution in the SEFRT. The effects of various chemical contaminants on marine biota would also be useful to study. Harmful toxins were discovered to be associated with microplastics over the course of this project, but of the 5 found only 2 are known to be environmental hazards; studies aiming to quantify the effects of these toxins on marine life would allow for a full risk analysis for aquatic life along the SEFRT.

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