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Quantity and types of plastic waste in Beaches: A case study of Al-Shuaybah beach, Saudi Arabia

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ABSTRACT

Plastic pollution is one of the major environmental concerns that are known to negatively impact marine life and human health. An evaluation of the availability, quantity, and types of plastic waste was conducted at Al-Shuaybah beach, Saudi Arabia. A total of 1504 different plastic pieces were collected from the sampling site; (i) 27.8% un-identified pieces; (ii) 22.7% water bottles; (iii) 21.7% bottle caps; (iv) 12.2% plastic bags; 5.6% spoons; (v) 4.7% plastic cups; (vi) 3.8% plastic straws; (vii) 1% plastic masks; and (viii) 0.4% plastic fishing lines. The largest piece of plastic found was a bag with a dimension of 50 cm while the smallest was an un-identified piece with a dimension of 0.3 cm. The fishing lines were the heaviest (14.3 kg) followed by water bottles (5.2 kg) and water bottle caps (4.6 kg). Using CCI, the assessed beach was categorized as "extremely dirty" with plastic waste. The results indicate that beaches in Saudi Arabia are at risk of plastic pollution which could endanger marine life and indirectly affects human health. Increasing awareness on the harmful effects of plastic waste may assist in tackling this serious threat.

Key words: *Environmental health, Plastic, Plastic waste, Plastic pollution, Saudi Arabia*

Introduction

Plastics are defined as an artificial molding material consisting of diverse organic polymers and trace amounts of other substances. Plastics are widely employed in different sectors (building, packaging, automotive industry, construction and electronics) due to their unique characteristics such as being economical, convenient, light weighted, water resistant, and useful for electrical and thermal insulation and corrosion resistance (Hahladakis *et al.,* 2018). Basically, plastics are categorized into two classes; thermoset plastics and thermoplastics. Thermo-set plastics are known to harden upon heating in contrast to thermoplastics which soften.

Globally, production of plastic is estimated to be around 380 metric tons/year and is projected to reach up to 2000 metric ton/year by 2050 (Horton, 2022; Plastic Europe, 2021). According to the 2021 European report on plastic, plastic production in China, Japan and NAFTA countries (Mexico, Canada, and the United States) was 117.44, 11, and 69.73 metric tons/year respectively (Plastic Europe, 2021). The plastic production in Saudi Arabia is ap-

proximately 4.1 metric tons/year (Statista, 2020).

Plastic pollution is one of the major global environmental concerns due to the accumulation of plastic waste at lands, lakes, rivers and oceans. Plastics' accumulation in terrestrial and aquatic ecosystems is thought to be caused by its continuous consumption, rapid production, lack of proper waste management, and low rate of recycling (Alhazmi *et al.*, 2021; Geyer *et al*., 2017; Margallo *et al*., 2019; Nikiema and Asiedu, 2022). In addition, the persistent and hard-to-degrade nature of plastic has contributed toglobal plastic pollution (Barnes *et al.*, 2009). Based on previous reports, estimated plastic waste in Latin America, Africa and Asia was 8, 17, and 52 million tons/year respectively (James *et al.*, 2021; Lebreton and Andrady, 2019).

Plastic debris (micro and macro plastic) and other kinds of linked contaminants have been found to cause mutagenicity, carcinogenicity, and reproductive issuesin humans (Gasperi *et al.*, 2018). Also, it poses a threat to marine life, due to the ingestion of plastic debris and their entanglement with it (Gasperi *et al.,* 2018; Thompson *et al.*, 2004; Van Cauwenberghe *et al.*, 2013).

The issue of plastic waste management, recycling, and pollution have been previously investigated in different ecosystems (Faure *et al.*, 2015; Horton, 2022; Isangedighi *et al.*, 2020; Ita-Nagy *et al.*, 2021; Lahens *et al.,* 2018; Strand *et al.,* 2021). Many reports focused on the impact of plastic waste on the marine and extra-marine animals of aquatic ecosystems (Cyvin, *et al.*, 2021; Galloway, 2015; Gasperi *et al.*, 2018; Reddy, 2018; Thompson *et al*., 2004; Van Cauwenberghe *et al.*, 2013; Wilcox *et al.*, 2015). In Saudi Arabia, a few studies investigated plastic contamination in the marine environment, mixed surface, and treated wastewater (Hassan *et al.,* 2022; Picó *et al.*, 2021) but little information is available on the quantity and types of plastic waste on populated beach areas in Saudi Arabia. Hence, the purpose of this study is to determine the quantity and types of plastic waste in Al-Shuaybah beach in Saudi Arabia.

Materials and Methods

Study Area

The study was conducted at Al-Shuaybah beach in Saudi Arabia. A large section of the beach was randomly selected for sampling. The area for collection was around 65m*12.5m which equals to 812.5m^2. Anything other than plastic was not included in the analysis.

Sampling

All plastic waste was collected manually by the research team from the sampling areaduring wintertime, (January-February 2022). Any plastic, no matter how big or small, was eligible for collection (Wessel *et al.*, 2016). Separation of plastic waste from non-plastic items was performed by recognizing the specific physical properties associated with plastic after the completion of collection. Finally, quantification and recognition of macro and micro plastic was carried out through visual sorting. Clean Coast Index (CCI) was used to objectively measure the amount of plastic waste following this equation (Alkalay *et al.*, 2007):

$$\frac{\text{Total plastic parts counted in line}}{\text{beach length (m)} \times \text{beach width (m)}} = \text{Plastic parts/m}^2$$

0–0.1 parts/m^2 (very clean, no litter is seen)

0.1–0.25 parts/m^2 (clean, no litter is seen over a large area)

0.25–0.5 parts/m^2 (moderate, a few pieces of litter can be detected)

0.5–1 parts/m^2 (dirty, a lot of waste on the shore)

More than 1 part/m^2 (extremely dirty, most of the shore is covered with plastic debris)

Results

A total of 1504 plastic pieces were collected from the sampling area which were water bottles, bottle caps, bags, spoons, cups, straws, masks, and fishing lines (Table 1). The CCI calculations indicated that the beach was extremely dirty (1.85 Plastic parts/m^2) and most of the shore was covered with plastic debris as seen in Figure (1 and 2). The quantity of unidentified plastic pieces, water bottles, bottle caps, bags, spoons, cups, straws, masks, and fishing lines were 418 (27.8%), 342 (22.7%),327 (21.7%), 183 (12.2%), 85 (5.6%), 71 (4.7%), 57 (3.8%), 15 (1%) and 6 (0.4%) respectively (Table 1). The fishing lines were the heaviest plastic piece (14.3 kg) followed by water bottles (5.2 kg) and bottle caps (4.6 kg) (Table 1). The largest plastic found was a plastic bag with a dimension of 50 cm while the smallest was an unidentified piece of plastic with a dimension of 0.3 cm (Table 1). The dimensions of the water bottles, bottle caps, spoons, cups, straws, masks and fishing lines

Table 1. Detailed information about collected plastic wastes from populated beaches

Type of plastic	Quantity (%)	Dimensions (cm)	Weight (kg)*
Water bottles	342(22.7%)	8.1 – 42.4	5.2
Fishing lines**	6(0.4%)	25	14.3
Bottle caps	327(21.7%)	3.2	4.6
Bags	183(12.2%)	10 – 50	
Straws	57(3.8%)	9 – 20	
Masks	15(1%)	32	
Cups	71(4.7%)	9.8	
Spoons	85(5.6%)	7.5 – 16.5	
Others***	418(27.8%)	0.3 – 7.8	

*Total weight = 24.1 kg, and total quantity = 1504.
**Large chunks of fishing lines were found in six groups integrated together.
***Unknown plastic particles and pieces.
Note, (cm) = centimeters, and (kg) = kilograms.
The amounts of plastic listed above were found across 65m X 12.5m which equals 812.5 m².

Fig. 1. Shows the beach area before removing the plastic wastes.
Pictures of the beach area before removing the plastic wastes. Wastes were collected and brought back to the research center for further analysis.

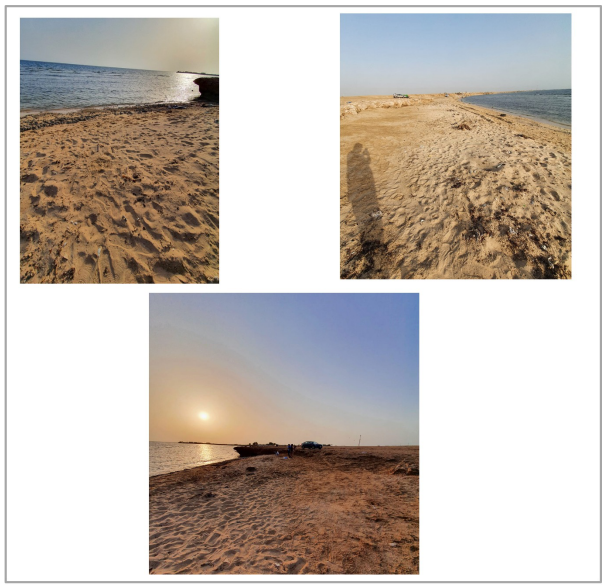

Fig. 2. Shows the beach area after removing the plastic wastes.
Pictures of the beach area after removing the plastic wastes, which was disposed in bins after finishing the analysis.

were 8.1-42.4 cm, 3.2 cm, 7.5-16.5 cm, 9.8 cm, 9-20 cm, 32 cm and 25 cm respectively (Table 1).

Discussion

This study assessed the availability, quantity and types of plastic waste at a beach in Saudi Arabia. The collected plastic waste was found across 65m* 2.5m which equals to 812.5 m². A total of 1504 plastic pieces were collected from the beach with a total weight of 24.1 kg. The calculation result of CCI indicated that the sampling location was extremely dirty. Most of the plastic waste was comprised of un-identifiable plastic pieces followed by water bottles, water bottle caps, and plastic bags, cups, straws, protective masks, and fishing lines. The heaviest waste was fishing lines followed by water bottles and water bottle caps. The dimensions of the plastic waste ranged from 0.3 cm to 50 cm with small un-identifiable plastic pieces to big plastic bags or big water bottles respectively.

A number of studies on plastic pollution monitoring using CCI were conducted previously in differ-

ent places including Israel, Philippines, Indonesia, Slovenia, and the Amazon region amongst many others (dos Santos Lima *et al*., 2022; Laglbauer *et al*., 2014; Lessy and Nagu, 2020; Marin *et al*., 2019; Rangel-Buitrago *et al*., 2021; Sajorne *et al*., 2021). Rangel-Buitrago *et al*., 2021 conducted a study on plastic pollution on the Colombian central Caribbean beaches. The authors reported that the study area was categorized as "extremely dirty" (Rangel-Buitrago *et al*., 2021). Sajorne *et al*., 2021 investigated plastic pollution on beaches in the Philippines. The authors found that calculated CCI indicated that around 76% of sampling sites were categorized as "dirty" and "extremely dirty" (Sajorne *et al*., 2021). Another recent report from Brazil indicated that around 68% of the studied sites were classified as "extremely dirty" (Marin *et al*., 2019). In comparison to other countries, results found in this study were relatively similar. This indicates how prevalent is plastic pollution globally.

Human activities such as fishing, solid waste disposal, coastal-industrial development, shipping, and tourism are the most likely sources of plastic waste in the ocean. The plastic waste collected at the beach could have arrived at the shore through waves stimulated by winds, surface current, and/or tides. Several lines of evidence demonstrated that plastic waste usually ends up at beaches by incoming tides, wind, and surface current (Caulton and Mocogni, 1987; Kitto and Sambhu, 2012; Neumann, 1966). Also, studies have shown that proximity to the beach, its location, type, slope, orientation, and physiography all affect the distribution of plastic waste (Dixon and Dixon, 1981; Thornton and Jackson, 1998; WADE, 1991; Whiting, 1998). Our investigation of the plastic pieces found on the beach led us to believe that they were most likely caused by inappropriate trashing of huge amounts of plastic materials like water bottles, bottle caps, bags, spoons, cups, straws, masks, fishing lines and other un-identifiable plastic pieces. One of the studies conducted on an 800 km shoreline of Oman and the Arabian Gulf indicated that the most prevalent ocean contaminant is plastic and mostly belongs to local origin (Khordagui and Abu-Hilal, 1994) which resonates with our findings.

It is well documented that plastic waste affects marine life and human health due to its continuous disposal in the ocean with an observed concentration of 5.8 lac pieces per km^2 (Barnes *et al*., 2009; Cózar *et al*., 2014; Law *et al*., 2010). Marine life is primarily affected by plastic through ingestion and entanglement. However, it impacts human health indirectly. A recent study conducted on 600 marine species (microorganisms to whales) found that plastic waste affects marine lifelargely through ingestion (Dias and Lovejoy, 2012). Many studies also showed the effects of plastic waste on seagull birds by impacting their reproduction and body condition (Gregory, 1978; Ryan, 2018; Wilcox *et al*., 2015). Moreover, previous studies demonstrated the toxicological effects of plastic waste on higher vertebrates of the ocean (Rochman *et al*., 2013; Talsness *et al*., 2009; Teuten *et al*., 2009). In addition, numerous reports showed that chemicals (phthalate and bis-phenol-A) employed in the formation of plastic had adverse impacts on human health, in general, and on the reproductive system, in particular (Lang *et al*., 2008; Swan, 2008; Swan *et al*., 2005). Finally, urinary concentration of phthalate has been found to be associated with a higher risk of cardiovascular disease, type II diabetes, and malfunctioning of liver enzymes (Lang *et al*., 2008).

Hence, the waste management of plastic is essential to avoid the issues associated with the human health and the environment. It can be achieved by law enforcement, initiating local waste management programs/campaigns, promoting the participation of agencies and spreading the awareness about the harmful effects of plastic waste. Also, it is crucial to enhance the interaction between environmental scientists and locals as well as replace our habits of using plastic items with more environmentally friendly items.

This study is the first to assess plastic pollution using an objective measurement (CCI) in Saudi beaches. Even though the study provided insight on the quantity and types of plastic waste, it had its limitation which was the use of one beach only and a small sampling area compared to other reports. However, it is an important cornerstone for future studies investigating plastic pollution in Saudi beaches.

Conclusion

Plastic wasteis one of thebiggest global concerns as it affects humans and the environment. This study assessed the quantity and types of plastic waste at a local beach of Al-Shuaybah, Saudi Arabia and found that most of the pla0stic is thought to be of local origin and owing to inappropriate disposal by visitors

of the beach. Hence, decision makers must run regular campaigns to spread awareness among locals on the harmful effects of plastic waste on humans and the environment. Also, awareness must be raised regarding replacingplastic with other environmentally friendly materials.

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Conflict of interest

The authors declare no conflict of interest.

References

Alhazmi, H., Almansour, F.H. and Aldhafeeri, Z. 2021. Plastic waste management: A review of existing life cycle assessment studies. *Sustainability.* 13(10): 5340.

Alkalay, R., Pasternak, G. and Zask, A. 2007. Clean-coast index—a new approach for beach cleanliness assessment. *Ocean & Coastal Management.* 50(5-6): 352-362.

Barnes, D.K., Galgani, F., Thompson, R.C. and Barlaz, M. 2009. Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences.* 364(1526): 1985-1998.

Caulton, E. and Mocogni, M. 1987). Preliminary studies of man-made litter in the Firth of Forth, Scotland. *Marine Pollution Bulletin.* 18(8): 446-450.

Cózar, A., Echevarría, F., González-Gordillo, J. I., Irigoien, X., Úbeda, B., Hernández-León, S. and Ruiz, A. 2014. Plastic debris in the open ocean. *Proceedings of the National Academy of Sciences.* 111(28): 10239-10244.

Cyvin, J. B., Ervik, H., Kveberg, A. A. and Hellevik, C. 2021. Macroplastic in soil and peat. A case study from the remote islands of Mausund and Froan landscape conservation area, Norway; implications for coastal cleanups and biodiversity. *Science of the Total Environment. 787*, 147547.

Dias, B. and Lovejoy, T. E. 2012. Impacts of marine debris on biodiversity: current status and potential solutions. *CBD Technical Series. 67*: 11-26.

Dixon, T. R. and Dixon, T. J. 1981. Marine litter surveillance. *Marine Pollution Bulletin.* 12(9): 289-295.

dos Santos Lima, A. K., Silva, A. C., Pereira, L. F., Bezerra, C. M., Soares, L. S., de Castro, A. C. L. and Lourenço, C. B. 2022. Anthropogenic litter on the macrotidal sandy beaches of the Amazon region. *Marine Pollution Bulletin.* 184: 114124.

Faure, F., Demars, C., Wieser, O., Kunz, M. and De Alencastro, L. F. 2015. Plastic pollution in Swiss surface waters: nature and concentrations, interaction with pollutants. *Environmental Chemistry.* 12(5): 582-591.

Galloway, T. S. 2015. Micro-and nano-plastics and human health. In *Marine Anthropogenic Litter* (pp. 343-366): Springer, Cham.

Gasperi, J., Wright, S. L., Dris, R., Collard, F., Mandin, C., Guerrouache, M. and Tassin, B. 2018. Microplastics in air: are we breathing it in? *Current Opinion in Environmental Science & Health.* 1: 1-5.

Geyer, R., Jambeck, J. R. and Law, K. L. 2017. Production, use, and fate of all plastics ever made. *Science Advances.* 3(7): e1700782.

Gregory, M.R. 1978. Accumulation and distribution of virgin plastic granules on New Zealand beaches. *New Zealand Journal of Marine and Freshwater Research.* 12(4): 399-414.

Hahladakis, J. N., Velis, C. A., Weber, R., Iacovidou, E., & Purnell, P. 2018. An overview of chemical additives present in plastics: Migration, release, fate and environmental impact during their use, disposal and recycling. *Journal of Hazardous Materials.* 344: 179-199.

Hassan, I. A., Younis, A., Al Ghamdi, M. A., Almazroui, M., Basahi, J. M., El-Sheekh, M. M. and Hajjar, D. 2022. Contamination of the marine environment in Egypt and Saudi Arabia with personal protective equipment during COVID-19 pandemic: A short focus. *Science of the Total Environment.* 810: 152046.

Horton, A. A. 2022. Plastic pollution: When do we know enough? *Journal of Hazardous Materials.* 422: 126885.

Isangedighi, I. A., David, G. S. and Obot, O. I. 2020. Plastic waste in the aquatic environment: impacts and management. In *Analysis of Nanoplastics and Microplastics in Food* (pp. 15-43): CRC Press.

Ita-Nagy, D., Vázquez-Rowe, I. and Kahhat, R. 2021. Prevalence of microplastics in the ocean in Latin America and the Caribbean. *Journal of Hazardous Materials Advances*. 100037.

James, K., Vasant, K., SM, S. B., Padua, S., Jeyabaskaran, R., Thirumalaiselvan, S. and Benjamin, L. V. 2021. Seasonal variability in the distribution of microplastics in the coastal ecosystems and in some commercially important fishes of the Gulf of Mannar and Palk Bay, Southeast coast of India. *Regional Studies in Marine Science.* 41: 101558.

Khordagui, H. K. and Abu-Hilal, A. H. 1994. Man-made litter on the shores of the United Arab Emirates on the Arabian Gulf and the Gulf of Oman. *Water, Air, and Soil Pollution.* 76(3): 343-352.

Kitto, M. R. and Sambhu, C. 2012. Litter pollution on the coastline of Obhur, Kingdom of Saudi Arabia. *Arab Gulf Journal of Scientific Research.* 30(2-3): 112-119.

Laglbauer, B. J., Franco-Santos, R. M., Andreu-Cazenave, M., Brunelli, L., Papadatou, M., Palatinus, A., Deprez, T. 2014. Macrodebris and microplastics

from beaches in Slovenia. *Marine Pollution Bulletin.* 89(1-2): 356-366.

Lahens, L., Strady, E., Kieu-Le, T.-C., Dris, R., Boukerma, K., Rinnert, E. and Tassin, B. 2018. Macroplastic and microplastic contamination assessment of a tropical river (Saigon River, Vietnam) transversed by a developing megacity. *Environmental Pollution.* 236: 661-671.

Lang, I. A., Galloway, T. S., Scarlett, A., Henley, W. E., Depledge, M., Wallace, R. B. and Melzer, D. 2008. Association of urinary bisphenol A concentration with medical disorders and laboratory abnormalities in adults. *Jama.* 300(11): 1303-1310.

Law, K. L., Morét-Ferguson, S., Maximenko, N. A., Proskurowski, G., Peacock, E. E., Hafner, J. and Reddy, C. M. 2010. Plastic accumulation in the North Atlantic subtropical gyre. *Science.* 329(5996): 1185-1188.

Lebreton, L. and Andrady, A. 2019. Future scenarios of global plastic waste generation and disposal. *Palgrave Communications.* 5(1): 1-11.

Lessy, M. R. and Nagu, N. 2020. Spatial distribution of beach macro-litter in Ternate Island, North Maluku–Indonesia. *World News of Natural Sciences. 31.*

Margallo, M., Ziegler-Rodriguez, K., Vázquez-Rowe, I., Aldaco, R., Irabien, Á. and Kahhat, R. 2019. Enhancing waste management strategies in Latin America under a holistic environmental assessment perspective: A review for policy support. *Science of the Total Environment.* 689: 1255-1275.

Marin, C. B., Niero, H., Zinnke, I., Pellizzetti, M. A., Santos, P. H., Rudolf, A. C. and Polette, M. 2019. Marine debris and pollution indexes on the beaches of Santa Catarina State, Brazil. *Regional Studies in Marine Science.* 31: 100771.

Neumann, H. 1966. Die Beziehung zwischen Wind und Oberflächenströmung auf Grund von Triftkartenuntersuchungen. *Deutsche Hydrografische Zeitschrift.* 19(6): 253-266.

Nikiema, J. and Asiedu, Z. 2022. A review of the cost and effectiveness of solutions to address plastic pollution. *Environmental Science and Pollution Research.* 1-27.

Picó, Y., Soursou, V., Alfarhan, A. H., El-Sheikh, M. A. and Barceló, D. 2021. First evidence of microplastics occurrence in mixed surface and treated wastewater from two major Saudi Arabian cities and assessment of their ecological risk. *Journal of Hazardous Materials.* 416 : 125747.

Plastic Europe. 2021. Plastics–The Facts 2021. An analysis of European plastics production, demand and waste data. Retrieved from Plastics–The Facts (2021). An analysis of European plastics production, demand and waste data.

Rangel-Buitrago, N., Mendoza, A. V., Mantilla-Barbosa, E., Arroyo-Olarte, H., Arana, V. A., Trilleras, J. and Williams, A. T. 2021. Plastic pollution on the Colombian central Caribbean beaches. *Marine Pollution Bulletin.* 162: 111837.

Reddy, S. 2018. Plastic pollution affects sea life throughout the ocean. *The Pew Charitable Trusts. 14.*

Rochman, C. M., Hoh, E., Kurobe, T. and Teh, S. J. 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports,* 3(1): 1-7.

Ryan, P. G. 2018. Entanglement of birds in plastics and other synthetic materials. *Marine Pollution Bulletin,* 135: 159-164.

Sajorne, R. E., Bacosa, H. P., Cayabo, G. D. B., Ardines Jr, L. B., Sumeldan, J. D., Omar, J. M. and Creencia, L. A. 2021. Plastic litter pollution along sandy beaches in Puerto Princesa, Palawan Island, Philippines. *Marine Pollution Bulletin.* 169: 112520.

Statista. 2020. Petrochemical production of Saudi Basic Industries Corporation (SABIC) from 2019 to 2020, by type. Retrieved from https://www.statista.com/statistics/1246217/petrochemical-production-of-saudi-basic-industries/

Strand, K. O., Huserbråten, M., Dagestad, K.-F., Mauritzen, C., Grøsvik, B. E., Nogueira, L. A. and Röhrs, J. 2021. Potential sources of marine plastic from survey beaches in the Arctic and Northeast Atlantic. *Science of the Total Environment.* 790: 148009.

Swan, S. H. 2008. Environmental phthalate exposure in relation to reproductive outcomes and other health endpoints in humans. *Environmental Research.* 108(2): 177-184.

Swan, S. H., Main, K. M., Liu, F., Stewart, S. L., Kruse, R. L., Calafat, A. M. and Sullivan, S. 2005. Decrease in anogenital distance among male infants with prenatal phthalate exposure. *Environmental Health Perspectives.* 113(8): 1056-1061.

Talsness, C. E., Andrade, A. J., Kuriyama, S. N., Taylor, J. A. and Vom Saal, F. S. 2009. Components of plastic: experimental studies in animals and relevance for human health. *Philosophical Transactions of the Royal Society B: Biological Sciences.* 364(1526): 2079-2096.

Teuten, E. L., Saquing, J. M., Knappe, D. R., Barlaz, M. A., Jonsson, S., Björn, A. and Yamashita, R. 2009. Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B: Biological Sciences.* 364(1526): 2027-2045.

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. and Russell, A. E. 2004. Lost at sea: where is all the plastic? *Science.* 304(5672): 838-838.

Thornton, L. and Jackson, N. L. 1998. Spatial and temporal variations in debris accumulation and composition on an estuarine shoreline, Cliffwood Beach, New Jersey, USA. *Marine Pollution Bulletin.* 36(9): 705-711.

Van Cauwenberghe, L., Vanreusel, A., Mees, J. abd Janssen, C. R. 2013. Microplastic pollution in deep-sea sediments. *Environmental Pollution.* 182: 495-499.

WADE, B.A. 1991. A study of beach litter in Jamaica. *Caribbean Journal of Science. 27*: 190-197.

Wessel, C. C., Lockridge, G. R., Battiste, D. and Cebrian, J. 2016. Abundance and characteristics of microplastics in beach sediments: insights into microplastic accumulation in northern Gulf of Mexico estuaries. *Marine Pollution Bulletin.* 109(1): 178-183.

Whiting, S. D. 1998. Types and sources of marine debris in Fog Bay, Northern Australia. *Marine Pollution Bulletin.* 36(11): 904-910.

Wilcox, C., Van Sebille, E. and Hardesty, B. D. 2015. Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences.* 112(38): 11899-11904.