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Potential interaction between plastic litter and green turtle *Chelonia mydas* during nesting in an extremely polluted beach

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ABSTRACT

This study examines the extent of macroplastic pollution on Samandağ beach and the potential effects on green sea turtles during nesting. For this purpose, a total of 39 different turtle tracks were studied. Mean plastic concentration was found to be 19.5 ± 1.2 pcs m^{-2}. Among the different types of crawling, the highest concentrations of plastics were found on the tracks of turtles that did not attempt to dig nests (25.9 ± 8.4 pcs m^{-2}). In total, 7 different types of plastics (disposable, film, fishing-related, foam, fragments, miscellaneous, and textile) were found, with film-type plastics being the most prevalent (11 pcs m^{-2}). Samandağ beach was found to be greatly more polluted than any other beach in the Mediterranean Sea. We concluded that this pollution can cause negative effects, especially entanglement and entrapment, on green sea turtle females and hatchlings.

1. Introduction

Between 1950 and 2017, plastics manufacturing increased from 1.5 million tons to 355 million tons (PlasticEurope, 2016). As a result, the amount and extent of plastic pollution on land and at sea increased (Jambeck et al., 2015; Nelms et al., 2016; Lebreton et al., 2018). Once plastics reach a marine environment, they become a global problem by continuing beyond the countries from where they were discarded or reached the sea (Law et al., 2010; Lavers and Bond, 2017; Monteiro et al., 2018). One of the most significant areas of plastic litter accumulation are sandy beaches, which are also important areas for sea turtles to lay eggs. Not only marine litter but also sea level increases and coastal destruction (Fuentes et al., 2010; Nelms et al., 2016) significantly affect sandy beaches. Sandy beaches are a dumping ground for plastic waste, which, over time, accumulates, gets buried under the sand due to various factors, and becomes trapped at different depths (Poeta et al., 2014). As a result, plastics of different types and sizes present on the nesting beaches of sea turtles can make the nesting activities quite difficult (Ivar do Sul et al., 2011; Turra et al., 2014; Nelms et al., 2016). Different types of plastic litter that accumulates on beaches, ranging in different sizes from large fishing nets to microscopic particles, can pose a threat towards female turtles and newborn hatchlings (Ivar do Sul et al., 2011; Triessnig et al., 2012; Turra et al., 2014; Nelms et al., 2016). Nelms et al. (2016) group the risks that plastics pose towards sea turtles under the headings of ingestion, entanglement, impacts on nesting beaches and ecosystem effects. Among these risks, those grouped under the headings of entanglement, impacts on nesting beaches and ecosystem effects pose the greatest risk of significant negative effects on the turtles in pre-nesting, nesting and post-nesting periods. This applies for all seas and oceans of the world. From open ocean to closed basins, sand dunes are an important accumulation point for marine plastics regardless of the environment (Cozar et al., 2015). One of these closed basins is the Mediterranean. Closed seas like the Mediterranean possess a high level of plastic pollution (Cozar et al., 2015; Suaria et al., 2016). The Mediterranean is a closed sea that has 21 countries on its coasts and 10% of the global coastal population living on its shores (Cozar et al., 2015). It contains some of the busiest maritime traffic lanes in the world and receives the flow of several large rivers that are burdened with very large populations (Ceyhan, Ebro, Nile, Orontes, Po, Seyhan etc.) (Cozar et al., 2015). Significant population burden is one of the main sources of the severe pollution in the Mediterranean. Many researchers state that the Mediterranean is an important plastic litter collection area and consider it the 6th major garbage patch in addition to the 5 major garbage patches present in the world's oceans (Lebreton et al., 2012; Cozar et al., 2015; Suaria et al., 2016). In addition, the Cilicia sub-basin is the most severely polluted area in the Mediterranean with regards to plastic pollution (Liubartseva et al., 2018). Furthermore, the Levantine shores of Turkey, is one of the most heavily plastic-polluted areas in the Mediterranean (Gündoğdu, 2017). Another study reports that this area

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receives a significant amount of litter originating from other countries on the Eastern Mediterranean coasts, such as Syria, Egypt, Lebanon, Palestine and Israel (Gündoğdu and Çevik, 2017). Marine plastic pollution indicates coastal plastic pollution as well. In their study evaluating especially medical waste, Özdilek et al. (2006) report the litter amount on the Samandağ beaches on the Levantine shores of Turkey as 1251 g m^{-1}. They have also stated that this amount of litter affected green sea turtles (*Chelonia mydas*) that use this area as a nesting ground (Özdilek et al., 2006). Additionally, Sönmez (2018) stated that fishing activities and marine pollution account for most of stranded turtles found on the Samandağ coast.

This study establishes the risks of the plastic pollution on green sea turtles at Samandağ beach. This study aims to (1) determine the composition and amount of plastics on green sea turtles tracks, (2) assess how much these plastics vary between different beach zones based on whether green sea turtles can lay eggs or not and (3) determine the potential risks these plastics pose towards green sea turtles.

2. Materials and methods

2.1. Study area

Sampling was performed on the sandy beaches of the Samandağ coast on the northeastern Levantine coasts of Turkey between June–August 2018 (Fig. 1), which corresponds with the highest nesting activity period of the sea turtles.

2.2. Selection of turtle tracks

Four different types of sampling tracks were studied:

1- Tracks belonging to turtles that crawled out of the sea and laid eggs;
2- Tracks belonging to turtles that crawled out of the sea and nested, but did not lay any eggs;
3- Tracks belonging to turtles that crawled out of the sea but returned to the sea without digging; and
4- Tracks belonging to the hatchlings.

Sample for the first case were taken from three locations: the nest and its surroundings, at the midpoint of the beach along the track, and at the point of crawling (high tide line). A similar sample collection was performed for the second case. For the third case, because there was no nest-digging activity, samples were taken from the point the turtle turned back and headed to the sea, and the high tide line where the turtle returned to the sea and crawled out of the sea. For the fourth case, samples were taken from the nest that the hatchlings emerged from and its surroundings, at the midpoint of the beach along the track and the high tide line at the location the hatchlings entered the water (Fig. 2). Sampling was performed using 1 × 1 quadrants (Fig. 2).

2.3. Plastic sampling

During the study, plastic sampling was performed between June and August 2018, on different days when the wind was at a minimum (2 knots maximum). Sampling was performed by following the crawling tracks left by female turtles the previous night and the tracks of the hatchlings that emerged from the nests, as shown in Fig. 2. Tracks belonging to the turtles that dug nests and laid eggs were marked and these nests were ignored while sampling the hatchling tracks. Samples were taken using 1 × 1 quadrants and plastics on the surface were collected. First 2 cm of sediment were controlled and plastics larger than 2.5 cm were collected. This study takes into consideration plastics

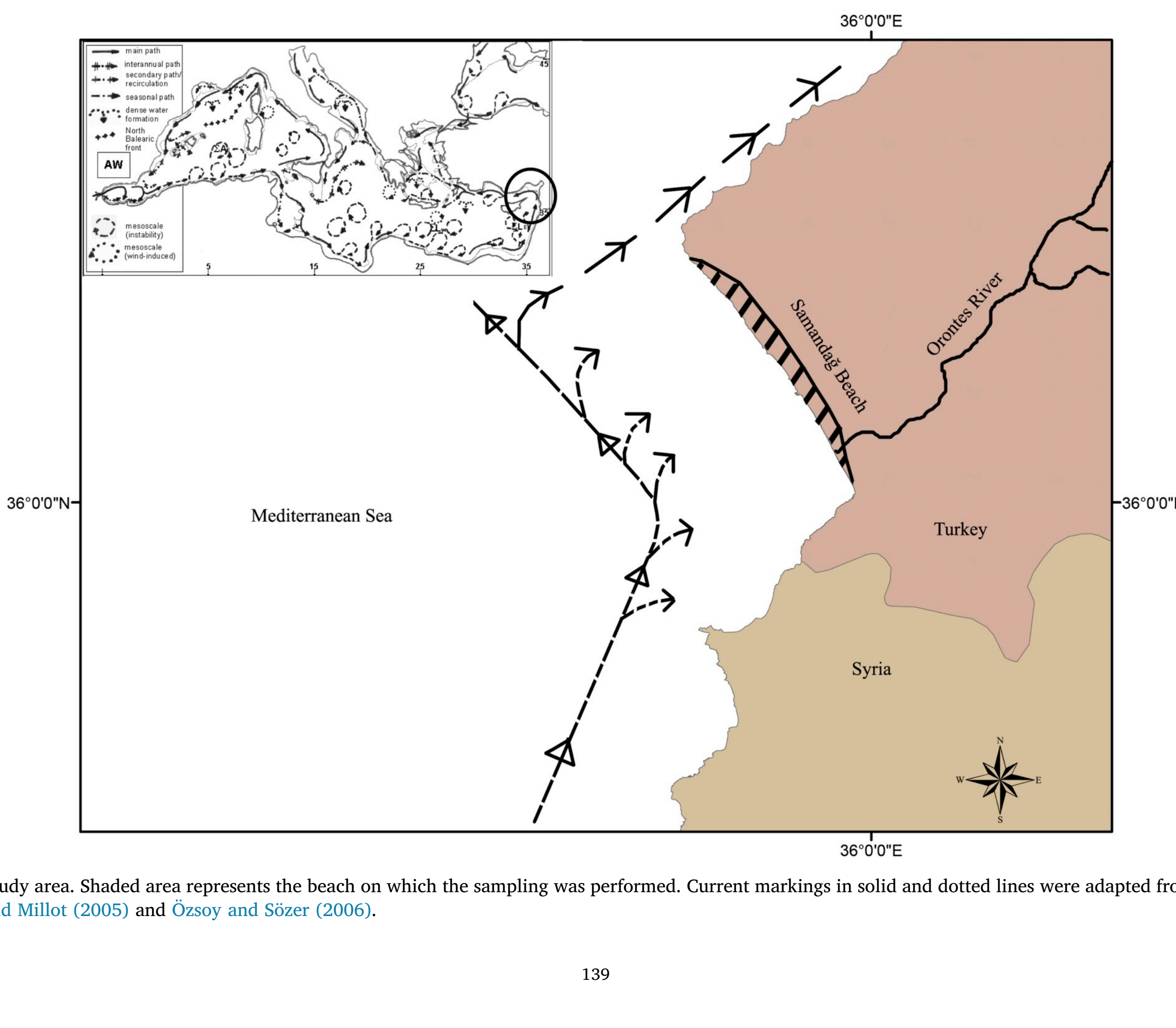

Fig. 1. Study area. Shaded area represents the beach on which the sampling was performed. Current markings in solid and dotted lines were adapted from Taupier-Letage and Millot (2005) and Özsoy and Sözer (2006).

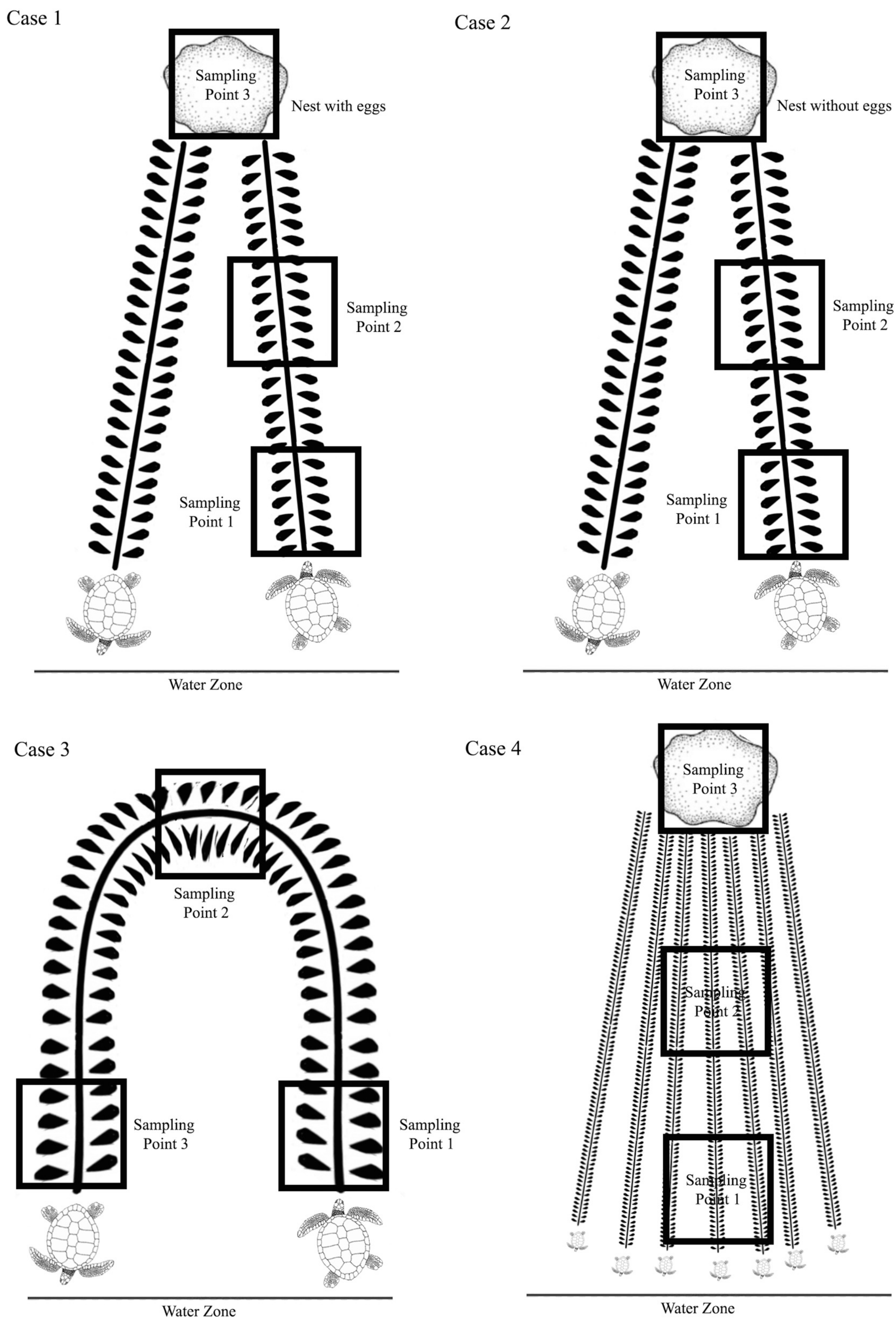

Fig. 2. Representative illustration of turtle tracks encountered during the sampling study and the placement of quadrants on the tracks.

that can pose a risk to green sea turtle hatchlings and adult females and that are larger than the 2.5 cm recommended by Van Cauwenberghe et al. (2015) for the definition of macroplastics. In a previous study performed in the same area by Sönmez (2010), green sea turtle hatchling carapaces were measured as 4.5 cm and head width was measured as 1.2 cm. The points on the turtle tracks used for plastics sampling followed the beach sampling methodology provided by Losh (2015). According to this methodology, if possible, samples should be taken from three points starting at the last high tide line (sampling point 1 in Fig. 2), at the middle of the beach (sampling point 2 in Fig. 2) and at the end of the beach (sampling point 3 in Fig. 2). Aside from the tracks of the turtles that crawled out of the sea but did not perform any nesting activity, the methodology provided by Losh (2015) was followed with some modification. Accordingly, the fact that the plastics at

Table 1
Categories of plastics collected during sampling.

Group	Categories
Fishing related	Rope
	Nets
	Line
Disposable items	Straw
	Pet cups
	Pet bottle
	Plastic sack
Foam and foam rubber	Foam cups
	Foam rubber
Film	Wrappers
	Nylon bags
	PE greenhouse covers
Textile	Shoes
Plastic fragments	Broken hard plastics
Miscellaneous	Medical items
	Toys
	Cigarette box nylon

2.5 cm and above were visible and that the turtles were mixing up the sand when they crawling eliminated the need for a sand sieving process. Finally, at each point the plastic occurrence was recorded within 1 × 1 quadrats, without extra digging or removal sand or plants (Poeta et al., 2016).

2.4. Plastic classification

All plastic items that fell in the quadrants were classified based on the classification provided in Schmuck et al. (2017) (Table 1).

2.5. Statistical analysis

The presence of plastics was given as $pcs\,m^{-2}$ ± SE. ANOVA was used to test if there were any differences with regards to plastic concentration among landing types (hatchling tracks: *OfT*, landing with nest and eggs: *NwiE*, landing with nest but without eggs: *NwoE* landing with no nest: *OnT*) and whether plastic types differed within the total. For multiple comparisons, the DUNCAN multiple comparison test was used. The relationship between sampling points on tracks with nests and eggs and tracks with nests but without eggs were tested using a Chi-Square independence test. All analysis was performed using SPSS v12 and the significance level was taken as 5%.

3. Results

During sampling, we counted plastics on 39 different turtle tracks. Among these turtle tracks, 13 belonged to hatchlings, 11 belonged to turtles that crawled out of the sea and laid eggs, 8 belonged to turtles that crawled out of the sea and nested but did not lay any eggs, and 7 belonged to turtles that crawled out of the sea but returned to the sea without digging. Plastics were discovered in all quadrants. The plastics concentration was found to be 19.5 ± 1.2 $pcs\,m^{-2}$ (Table 2). Among different types of crawling, the highest concentrations of plastics were found on the tracks of turtles that did not attempt to dig nests (25.9 ± 8.4 $pcs\,m^{-2}$; Fig. 3). In total, 7 different types of plastics (disposable, film, fishing-related, foam, fragments, miscellaneous, and textile) were found, with film-type plastics being the most prevalent (11 pcs/m^2) (Table 1; Table 2; Fig. 3). The numbers of plastics in different groups were significantly different (p = 0.00). Three separate groups were formed according to the DUNCAN test: The first group consisted of the film type plastics, second group consisted of the fragment type plastics (both are the most common types found in the sample) and the last group consisted of the other types of plastics. The order of the groups was *Film* > *Fragments* > *Foam* ≥ *Fishing related* ≥ *Misc.* ≥ *Textile*. The difference between plastics concentrations on turtle tracks was found to be statistically significant (p = 0.00).

According to the DUNCAN test, the order of turtle tracks based on plastic concentrations were *OnT* > *OfT* ≥ *NwiE* ≥ *NwoE*. Plastics concentrations obtained from the *NwiE* and the *NwoE* (also representing three different areas of the beach) were found to be statistically different (χ^2 = 7.47, p = 0.02). Among these tracks, the highest amount of plastics were found around the nests (21.31 ± 1.40 $pcs\,m^{-2}$) or the end of the beach, and the lowest amount was found in the middle area of the beach (16.97 ± 0.12 $pcs\,m^{-2}$).

Among the sampling points on the tracks, the differences regarding plastic pollution were only found to be significant for the *OnT* group (p = 0.00). In the OnT group, the plastics concentration, which was lower at the point where the turtles crawled out of the sea, was found to increase at the points where the turtles turned around and headed back to the sea, and to decrease back to the same level at the landing point where the turtles returned to sea (Fig. 4).

Table 3 illustrates the potential risks that the plastic types might pose on the turtles. The ratios in Table 3 and the percent abundance of the related plastic types show that Samandağ beaches are very problematic and risky nesting areas for green sea turtles.

4. Discussion

The significant abundance of plastics on the nesting beaches support the view that beaches are an accumulation area for plastics floating in seas and oceans. While it falls outside the scope of this study, it is worth noting that the number of plastics collected on the Samandağ beach was significantly higher than the numbers reported by previous studies conducted in the Mediterranean coastal areas (Table 4). It is likely that such a high accumulation of plastics on the beach might have had negatively affected the female turtles that came onto the beach to nest and the hatchlings that emerged from their nests.

The dominant current system in the Samandağ area is one of the most important reasons for this high concentration of plastics, as described in detail by Taupier-Letage and Millot (2005). Plastics and other floating litters that are dumped into the sea from countries around the Levantine Sea, such as Egypt, Lebanon, Palestine, Israel and Syria, are carried by this current system along the coast up to Samandağ and turn towards the bays of Mersin and Antalya in Turkey at a point off Samandağ (Fig. 1). During this time, large amounts of floating litter, like plastics and similar, accumulate on the Samandağ beaches. Litter from Syria, Lebanon and Egypt encountered frequently during the sampling, support this conclusion (Fig. 5). In addition, the Orontes River that flows to the sea at Samandağ is a significant carrier of litter. In a study performed in the area, Özdilek et al. (2006) reported that the amount of litter on the beach increased significantly closer to the Orontes River.

Litter accumulation on the beaches poses a significant risk towards many organisms that use the beaches in some way or another. Plastics litter, especially through entanglement (Schrey and Vauk, 1987; Gregory, 2009; Ryan et al., 2009; Votier et al., 2011), affects many groups of organisms. In addition, because plastics are not a natural part of the habitat, they might have undesired effects on the natural life cycles of many organisms. This can especially affect sea turtles in many ways. However, we encountered few studies on this subject aside from those that establish anectodal associations between litter amount and the number of nests or stranding rates (Dial, 1987; Claereboudt, 2004; Özdilek et al., 2006; Tomillo et al., 2010). Two significant studies on this subject are by Triessnig et al. (2012) and Duncan et al. (2018). Triessnig et al. (2012) reports that hatchlings emerging from nests get entangled or stuck inside plastics, causing a significant decrease in nest numbers in the long term. Among the film-type plastics found in this study, which accounted for one of the highest amounts, package-shaped ones can cause the effects reported by Triessnig et al. (2012). Duncan et al. (2018) reports that microplastic pollution in turtle nests negatively affect the egg hatching success rate and gender ratios of the hatchlings. Both studies show that severe plastic pollution on the

Table 2
Numbers of plastics on turtle tracks based on type (hatchling tracks: *OfT*, landing with nest and eggs: *NwiE*, landing with nest but without eggs: *NwoE* landing with no nest: *OnT*; *Sp:* Sampling point). Small letters indicate the statistical difference.

		Plastic group (number)							Grand total	Grand mean ± SE (number m^{-2})
		Disposable	Film	Fishing related	Foam	Fragments	Misc	Textile		
OnT[a]	Sp. 1	1	14	4	3	46	0	0	516	25.9 ± 8.4
	Sp. 2	7	133	18	15	121	1	0		
	Sp. 3	8	59	4	7	74	1	0		
OfT[b]	Sp. 1	12	169	11	4	122	0	0	737	22.2 ± 3.1
	Sp. 2	0	45	8	2	57	1	0		
	Sp. 3	16	160	6	22	95	6	1		
NwoE[b,c]	Sp. 1	1	64	5	3	36	2	0	388	17.8 ± 2.6
	Sp. 2	1	66	1	4	46	0	0		
	Sp. 3	5	67	9	11	64	3	0		
NwiE[c,d]	Sp. 1	9	106	11	5	99	3	0	640	20.1 ± 1.8
	Sp. 2	4	106	5	11	61	1	0		
	Sp. 3	10	115	6	19	64	4	1		
Grand total	**Sp. 1**	23	353	31	15	303	5	0	**2281**	**19.5 ± 1.2**
	Sp. 2	12	350	32	32	285	3	0		
	Sp. 3	39	401	25	59	297	14	2		
Grand mean (number m^{-2})		12.3	184.0	14.7	17.7	147.5	4.4	0.3		

beaches affects females and hatchlings negatively, both biologically and physically. In addition, the average plastic pollution amount present in the study areas of both researchers are significantly lower than the concentration found in this study. This shows that the concentration of plastic pollution present on Samandağ beaches poses a significant risk towards green sea turtles that use the area for nesting. For instance, looking at Fig. 4, the *OnT* group are thought to be affected by the concentration of plastic pollution at the point where they turned back and headed to the sea. Of course, it is known that turtles crawl multiple times before laying eggs and might return to the sea without laying eggs due to many factors including lights, sounds, tourism activities and characteristics of the sand (Kikukawa et al., 1999; Triessnig et al., 2012). However, it is also known that anthropogenic effects are limited in the area that this study was performed, and sand characteristics do not vary significantly along the length of the beach (Sönmez, 2010). Taken into consideration with the plastics concentration detected for the *OnT* group, this suggests that plastics concentration is a factor that might affect this situation. Green sea turtle females are philopatric and they visit the beaches they were born every year to nest (Lee et al., 2007; Nishizawa et al., 2011). Needless to say, this is directly related to the overall condition of the beaches. If they do not choose to nest on their natal beach, they might return to the sea without laying eggs (Chacón-Chaverri and Eckert, 2007; Nelms et al., 2016). Plastic litter

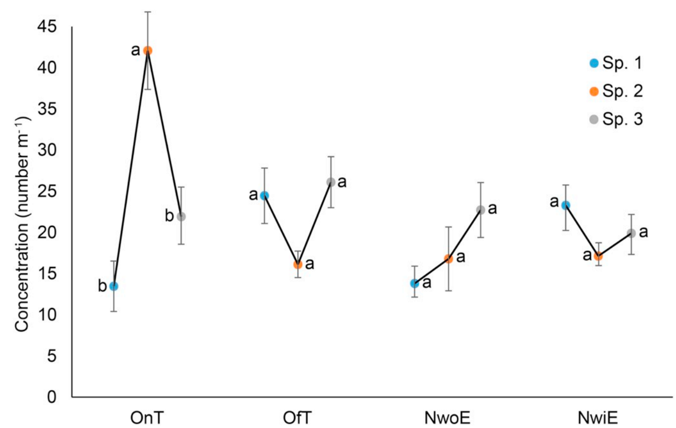

Fig. 4. Plastics concentrations in different crawling types and sampling quadrants. The bars show standard errors and small letters indicate the statistical difference (hatchling tracks: *OfT*, landing with nest and eggs: *NwiE*, landing with nest but without eggs: *NwoE* landing with no nest: *OnT*).

can be a determining factor in the decision to nest or not to nest. In that regard, Samandağ beach carries a risk because large pieces of plastic litter continued to accumulate on the sandy beaches from the marine

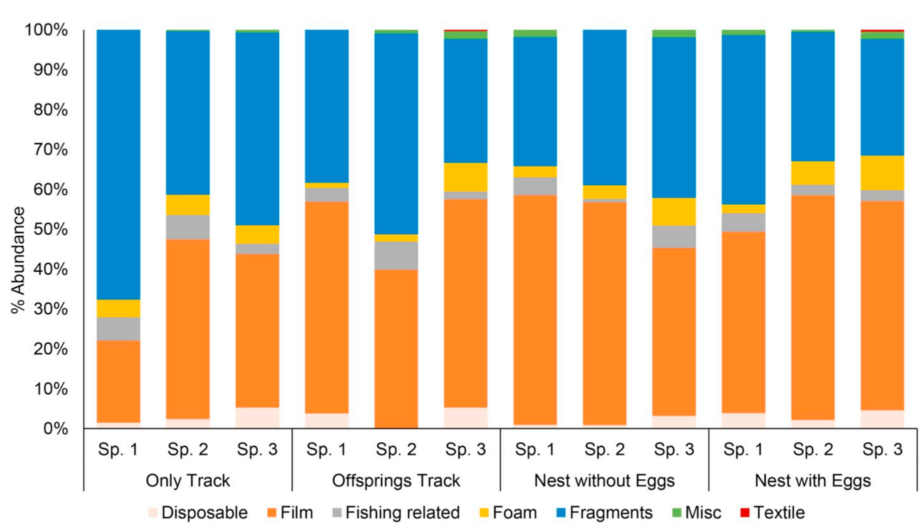

Fig. 3. Abundance percentage of plastic types on turtle tracks (*Sp:* Sampling point).

Table 3
Abundance and potential effects of collected plastics.

Plastic group	Categories	Abundance (%)	Potential effects
Fishing related	Rope	3.33	- Entanglement
	Nets	0.26	- Reduce nesting success
	Line	0.26	
Disposable items	Straw	0.09	- Barrier for offspring to reach sea
	Pet cups	2.37	- Reduce nesting success
	Pet bottle	0.66	- Becoming microplastics and increase the permeability and decrease the temperature of sediment
	Plastic sack	0.13	- Entrapping effect
Foam and foam rubber	Foam cups	2.94	- Becoming microplastics and increase the permeability and decrease the temperature of sediment
	Foam rubber	1.71	- Entrapping effect
Film	Wrappers	12.1	- Entanglement,
	Nylon bags	0.79	- Reduce nesting success,
	PE greenhouse covers	35.51	- Becoming microplastics and increase the permeability and decrease the temperature of sediment
			- Entrapping effect
Textile	Shoes	0.09	- Barrier for offspring to reach sea,
			- Entrapping effect
			- Reduce nesting success
Plastic fragments	Broken hard plastics	38.8	- Barrier for offspring to reach sea
			- Reduce nesting success,
			- Becoming microplastics and increase the permeability and decrease the temperature of sediment
Miscellaneous	Medical items	0.7	- Reduce nesting success,
	Toys	0.13	- Becoming microplastics and increase the permeability and decrease the temperature of sediment
	Cigarette box nylon	0.13	- Entrapping effect

environment throughout the sampling period (Fig. 5). At this stage of the study, it is not possible to conclude if plastic litter is the reason for the turtles in the OnT group to return to the sea without laying eggs. Tracking studies based on genetic marking and satellite tracking are required to determine the reason.

Nelms et al. (2016) states that macroplastics in the sand might prevent hatchlings from reaching the surface after hatching from the eggs. In this regard, it should be noted that the 19.5 pcs m^{-2} macroplastic of Samandağ beach constitutes a serious risks. Furthermore, this represents only the amount of plastics found on the surface. Therefore, more detailed studies are needed to determine the number of macroplastics in the sand column.

5. Conclusion

Sea turtles, especially hatchlings, are some of the few organisms that are affected by threats from both marine and terrestrial environments (Triessnig et al., 2012). In the sea, natural predators reduce the number of hatchlings, while factors like commercial fishing, maritime traffic, etc., reduce the number of adults (Finkbeiner et al., 2011). Anthropogenic threats towards adult and young individuals present in the marine environments were studied sufficiently, but studies on plastic pollution, one of these anthropogenic factors, during nesting are much more limited in number. This study also contributes to understanding the gravity of the problem. There is significant pollution and predation pressure on sea turtle females and hatchlings on Samandağ beaches. Many dead adults and hatchlings were encountered in the area during the study. These deaths, due mostly to predatory animals (ghost crab, seagull etc.), demonstrate a significant pressure on green sea turtles are on Samandağ beaches. A severe plastics pollution in addition to the already existing pressures suggests that the go through a quite difficult reproduction season. Furthermore, the local authorities who manage the plastics pollution by using tractors to plough the beach also pose a significant problem. Plastic litter, which float in the sea for long periods, becomes prone to fracturing into smaller particles due to various factors. Plastics that have accumulated on the beaches of Samandağ can easily break down into microplastics by activities such as ploughing by tractor, and reach deeper sand layers. Duncan et al. (2018) reports that microplastics present in turtle nests significantly affect the ability to hatch and the gender ratios of hatchlings. This situation shows the necessity to establish a coast management plan taking all these factors into consideration, specifically with regards to the Samandağ beach.

Table 4
Plastic waste amounts reported in studies performed in other coastal areas of the Mediterranean.

Study area	N of surveyed beach	Sampling type	Average plastic density (pcs m^{-2})	Reference
Turkey (Gulf of Fethiye)	1	100 m long transect	1.0	(Triessnig et al., 2012)
Turkey (Western Black Sea Coast)	10	20 m long transect	0.9	(Topcu et al., 2013)
Slovenia	6	50 m long transect	1.5	(Laglbauer et al., 2014)
Italy (Northern Adriatic coast)	5	50 × 50 cm quadrats	0.2	(Munari et al., 2017)
Italy (Tyrrhenian coast)	5	2 × 2 m quadrats	0.9	(Poeta et al., 2016)
Turkey (Sarıkum lagoon coast)	1	None	4.5	(Visne and Bat, 2016)
Italy (Pelagos sanctuary)	4	100 m long transects	1.1	(Giovacchini et al., 2018)
Croatia			2.9	(Vlachogianni et al., 2018)
Adriatic & Ionian Sea	31	100 m long transect	0.7	
Slovenia			0.5	
Montenegro			0.4	
Italy			0.3	
Greece			0.2	
Albania			0.2	
Bosnia & Herzegovina			0.2	
Turkey	1	1 × 1 m quadrats	19.5	This Study

Fig. 5. Macroplastics from Egypt, Lebanon and Syria present on the beach.

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