



Marine Plastic Litter in Phu Quoc Marine Protected Area, Vietnam: Current Status and Mitigation Approaches

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<http://doi.org/10.29227/IM-2022-02-13>

Submission date: 19-08-2022 | Review date: 22-11-2022

Marine plastic pollution causes adverse effects on global environment and marine ecosystems, particularly in marine protected areas. However, little is known of the effects of marine plastic debris on marine ecosystem services, human wellbeing, society, and the economy. We selected Phu Quoc Marine Protected Area (Phu Quoc MPA) for gaining an insight into current marine plastic debris as a first step towards understanding its effects on the environment and biodiversity in the region. This study applied secondary data analysis, semi-structured interviews, field measurements, and the quadrat line transect method in pursuit of the objective of the study. The findings reveal that marine plastic debris disposed of in Phu Quoc MPA dominantly came from diverse sources including rivers, streams, canals, tourism service providers, and marine aquaculture development areas. The abundance of macroplastic on the beaches was approximately between 1.109 and 0.248 items/m² (equivalent to 0.082 ± 0.021 kg/m²). Most of the macroplastic were single-use plastics and accounted for more than 82%. The average size was approximately 14.932 ± 1.846 cm for items less than 30 cm. The remaining ones were HDPE plastic bags and plastic debris. The macroplastic and microplastic need to be stopped in order to encourage sustainable management of waste in the region.

Keywords: macro-plastic, micro-plastic, marine protected area, Phu Quoc, Vietnam, policy recommendations, single-use plastics

1. Introduction

Marine ecosystems provide a wealth of ecosystem services including food provision, carbon storage, waste detoxification, and cultural benefits (Worm et al., 2006; Lique et al., 2013). Any threat to these services is highly likely to significantly impact human wellbeing (Naeem et al., 2016). Plastics, despite widespread use, cause environmental pollution, particularly in the marine ecosystem. Approximately 360 million metric tons of plastic were produced per year (PlasticsEurope, 2019). Of 9 million tons of plastic that ended up in the ocean annually, up to 12.7 million metric tons came from land-based sources in 2010 (Jambeck et al., 2015). Two-thirds of the global plastic waste came from polluted rivers in Asia (Lebreton et al., 2017). When entering the ocean, the plastic is normally chopped up into microplastics by marine vertebrates. Currently, about 15% of the world's sandy beaches are polluted with microplastics. Microplastics float at the water surface in the ocean and are eaten by plankton, fishes, and marine living things. Marine plastic debris will outnumber fishes by 2050 if no efforts are made to stop the disposal of plastic in the ocean (Jambeck et al., 2015). Previous studies showed that plastic disposal in the ocean poses negative impacts on marine life. However, little is known of the effects of marine plastic debris on marine ecosystem services, human wellbeing, society, and the economy. This knowledge is necessary, particularly in the context where plastic is increasingly consumed and there is a need for raising awareness, revising, and/or amending legislation and laws.

We selected Phu Quoc Marine Protected Area (Phu Quoc MPA), Kien Giang, Vietnam for understanding current ma-

rine plastic debris as a first step towards understanding its effects on the marine life because the island represents a good case study in this regard. Phu Quoc island becomes a popular destination locally and regionally thanks to its natural landscapes and biodiversity. The government at all levels invested a significant amount of capital in constructing infrastructure that serves tourism development in addition to service-oriented facilities such as hotels, resorts invested by private sector. This tourism development resulted in serious terrestrial and marine pollution. Plastic waste is a main cause of pollution in accordance with Phu Quoc City People's Committee (Phu Quoc PC) in 2020. Phu Quoc generated 190 tons of municipal solid waste (MSW) per day, 170 tons of which were daily collected by staff working for the Public Work Management Board. In addition, wastes were not properly treated and are still seen in terrestrial and aquatic ecosystems. In accordance with WWF in 2018, plastic waste accounted for 20% of total wastes (about 30 tons/day) that were generated in Phu Quoc on a daily basis. About one-third were uncollected and disposed into the natural environment. However, there is limited information on marine plastic debris in the Phu Quoc MPA. This study, therefore, aims to investigate status of marine plastic litter in the Phu Quoc MPA and its sources for better recommendations of mitigation approaches. In this study, secondary data analysis, semi-structured interviews, and field measurements were employed in pursuit of the objective of the study. The findings of this study would provide technical references for improving sustainable management of marine plastic debris in Phu Quoc and elsewhere in the wider region. The paper consists of four sections. Following Section 1 which

Tab. 1. Phu Quoc Marine Protect Area
Tab. 1. Morski obszar chroniony Phu Quoc

No.	Beach	Coordinates		Status
		Long	Lat	
1	Ham Ninh	104.066319	10.211247	Village, national park
2	Mui Da Bac	104.070835	10.215790	Village, national park
3	Mui Cay Sao	104.078815	10.241158	Village, national park
4	Bai Bon	104.077616	10.316513	Village, national park
5	Mui Da Chong	104.078453	10.356091	Village, national park
6	Bai Thom	104.075593	10.375675	Island, national park
7	Hon Mot	104.070808	10.383311	island, national park

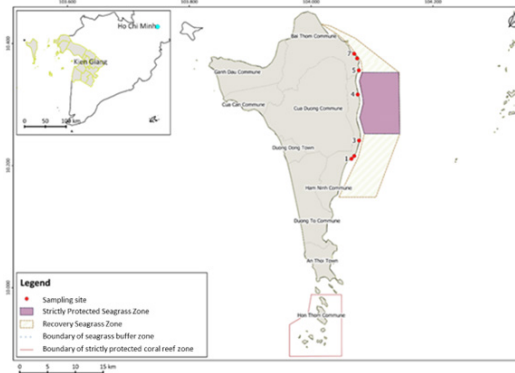


Fig. 1. The survey sites. The location of Phu Quoc in Kien Giang province and the Vietnamese Mekong Delta (on the left) and sampling sites in Phu Quoc island (on the right)

Rys. 1. Miejsca badań. Położenie Phu Quoc w prowincji Kien Giang i wietnamskiej delcie Mekongu (po lewej) oraz miejsca poboru próbek na wyspie Phu Quoc (po prawej)

Tab. 2. List of policies on marine plastic issues in Phu Quoc

Tab. 2. Lista zasad dotyczących postępowania z tworzywami sztucznymi w morzu w Phu Quoc

No.	Policy	Approved by	Year
1	Plan No. 231/KH-UBND dated 4 May 2020 of Phu Quoc City People's Committee launched the emulation movement for Phu Quoc Environment Day	PQ CPC	2020
2	Plan No. 274/KH-UBND dated 28 May 2020 of Phu Quoc District People's Committee to implement Phu Quoc Environment Day in June and respond to Environment Day (June 5), World Oceans Day (June 8), Vietnam Sea and Islands Week (June 1-8) in 2020	PQ CPC	2020
3	Decision No.45/QD-UBND dated 07 January 2020 of the Phu Quoc City People's Committee on establishing the Steering Committee for the implementation of the Action Plan on ocean plastic waste management in Phu Quoc City until 2025	PQ CPC	2020
4	Action plan No.545/KH-UBND dated 22 November 2019 of Phu Quoc District People's Committee on marine plastic waste management in Phu Quoc to 2025	PQ CPC	2019

is the Introduction, Section 2 describes methods used in this study. Section 3 and 4 present and discuss results against the literature. Section 5 presents a general conclusion.

2. Materials and methods

2.1 Site description

Phu Quoc MPA has two ecologically important areas, which are the coral reef zone and the seagrass beds. Phu Quoc MPA is ecologically and economically important because the MPA is key spawning and nursery area for many marine species and crucial fishing grounds locally and regionally. The MPA is home to many rare and endangered marine species such as Dugong, sea turtle, and dolphin. Previous studies show that the marine resources in Phu Quoc MPA were increasingly depleted due to rapid tourism growth.

Phu Quoc MPA contains seven sandy beaches, which are located in areas surrounding the strictly protected seagrass zone and recovery seagrass zone. Of the seven sandy beaches, five are sandy beaches located along the shoreline (Ham Ninh, Mui Da Bac, Mui Cay Sao, Bai Bon and Mui Da Chong). The two remaining ones are two islands (Bai Thom and Hon Mot). The survey sites are presented in Table 1 and Fig. 1.

2.2 Methods

The authors employed various methods in pursuit of the objective of the study. The methods included secondary data analysis, semi-structured interviews, field measurements, and the quadrat line transect method. Before undertaking field visits to Phu Quoc island, the authors collected reports and documents (secondary data analysis) related to marine plastic management and marine ecosystem in Vietnam and Phu Quoc island for adequately understanding current management of marine plastic waste in the region. The authors then contacted local authorities and staff working for Phu Quoc MPA for further data in relation to marine debris and the current waste management in Phu Quoc. The secondary data analysis provided a critical review of the current marine plastic debris and its management in Phu Quoc and assisted in developing open-ended questions which were subsequently used in semi-structured interviews with technical staff and local fishermen. The policies related to marine plastic litter reviewed collected were presented in Table 2.

This survey was organized from March to May 2021 with administrative support by local authorities and technical staff. During the field visits, the authors used the quadrat line

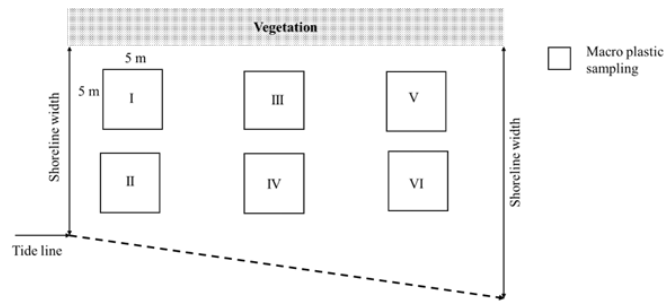


Fig. 2. Demonstration of random sampling methods for macro-plastic sampling
Rys. 2. Demonstracja metod losowego pobierania próbek makroplastiku

Tab. 3. Open-ended questions used in the semi-structured interviews

Tab. 3. Pytania otwarte użyte w wywiadach częściowo ustrukturyzowanych

Interviewees	Questions (English translation)
Local government officers and technical staff	<ol style="list-style-type: none"> 1. What was the area look like in the past? 2. What was sources of marine plastic litter? 3. How did plastic waste enter the marine environment? 4. How was Phu Quoc MPA polluted? 5. How did the pollution affect the marine environment and biodiversity? 6. Who was involved in marine litter? 7. Who was involved in waste management in Phu Quoc? 8. How was marine plastic debris managed? 9. What needs to be done to improve the management of marine plastic debris?
Local fishermen	<ol style="list-style-type: none"> 1. How did you dispose of your plastic waste? 2. What did you know about marine plastic pollution? 3. What was effects of marine plastic pollution on our environment and biodiverse? 4. How did you receive the information of marine plastic debris? 5. What should be done to prevent marine plastic litter?



Fig. 3. The marine plastic pollution at PQ MPA
Rys. 3. Zanieczyszczenie morza tworzywami sztucznymi w PQ MPA

transect method as suggested by de Carvalho and Baptista Neto (2016) for collecting marine plastics. Each quadrat is 5m x 5m. There were 19 samples collected at the seven beaches in this study from March to May 2021. At each beach, two to three quadrates (5mx5m) were randomly selected and recorded for classifying marine plastic debris (Fig. 2).

Plastic-related items were then collected, identified, and recorded using the techniques recommended by Lippiatt et al. (2013) (i.e. single-use plastic bags, single-use plastic cups, food packaging, plastic bottles, etc). The items were photographed and weighed using a portable electronic digital weighing scale to determine their relative composition (kg/m^2). The concentration of macroplastic (number of items/ m^2) was calculated using the method recommended by Lippiatt et al. (2013).

$$C = n/w * l$$

c – concentration of debris items (number of debris items/ m^2).

n – number of macro debris items observed.

w – transect width (m); l – transect length (m).

This method resulted in determining (1) macroplastics on the beaches; (2) sources of plastics pollution, and (3) compo-

sition and concentration of macroplastics on the beaches. The average (\pm standard errors) number of marine plastic items collected per 25 m^2 was calculated for each beach. The average concentration of marine plastic litters obtained (\pm se) was also analyzed for each site.

In addition, the authors interviewed local authorities, technical staff, and local fishermen using open-ended questions for understanding local perspectives on marine plastic pollution. The interview guide questions for each group were presented in Table 3.

3. Results and discussion

3.1 Distribution of marine plastic debris

The beaches were contaminated with a huge amount of marine plastic debris which came from the ocean (see Fig. 3).

The study revealed that the concentration of macroplastic on the beaches was approximately 1.109 ± 0.248 items/ m^2 , with the highest concentration being 2.533 items/ m^2 at Mui Da Bac and Bai Bon 1.6 items/ m^2 respectively. Ham Ninh and Mui Da Chong shared macroplastic density which was between 1.080 and 1.093 item/ m^2 respectively. Bai Thom and Mui Cay Sao beaches had the lowest level of macroplastic

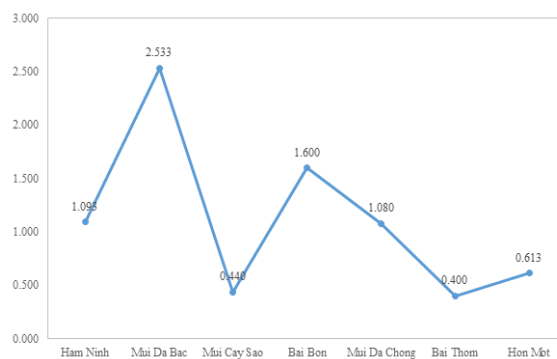


Fig. 4. The macroplastic density at the beaches

Rys. 4. Gęstość makroplastików na plażach

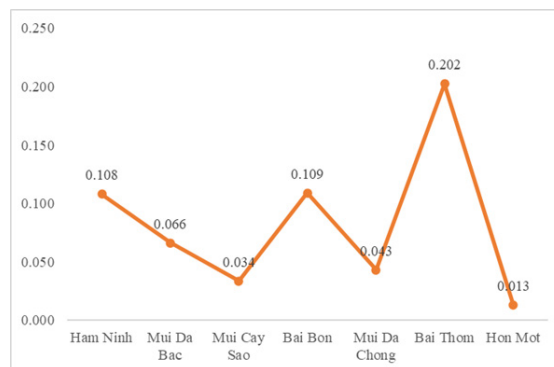


Fig. 5. Quantity of macroplastic at study areas

Rys. 5. Ilość makroplastików na badanych obszarach

Tab. 4. Sources and types of plastic waste

Tab. 4. Źródła i typy odpadów plastikowych

No.	Category	Number of items	Possible sources	
			Land-based source	Ocean-based source
1	Single-use plastic bags	192	Tourist, terrestrial origin	Sea
2	Single-use plastic straws & spoons	41	Tourist, terrestrial origin	
3	Plastic fragments	39	Tourist, terrestrial origin	Sea
4	Styrofoam	38	Tourist, terrestrial origin	
5	Single-use plastic cups	34	Tourist, terrestrial origin	
6	Plastic packaging/containers and film	34	Tourist, terrestrial origin	
9	Ghost nets (partly)	20		Fisheries
7	Food packaging	19	Tourist, terrestrial origin	
8	Plastic bottles	18	Tourist, terrestrial origin	
10	Plastic bottle caps	17	Tourist, terrestrial origin	
11	Food containers	16	Tourist, terrestrial origin	
12	Others (Diapers, sanitary napkins...)	11	Terrestrial origin	
13	Plastic lighters	7	Tourist, terrestrial origin	
14	Ropes and lines (partly)	6		Fisheries
15	Fishhooks	5		Fisheries
16	Cotton swabs	4	Terrestrial origin	
17	Plastic sandals & shoes	4	Terrestrial origin	

density being 0.400 and 0.440 items/m² respectively. Hon Mot beach was about 0.613 items/m² (Fig. 4).

The results confirmed that the concentration of macroplastic was related to the human use of the beaches. Beaches near the residential area or villages had a higher level of macroplastic concentration than those in the remote areas.

In comparison of quantity per square meter, Bai Thom beach had the highest quantity of marine plastic debris (about 0.202 kg/m²), followed by Bai Bon, and Ham Ninh beaches being 0.109 and 0.108 kg/m² respectively. The remaining beaches (Hon Mot, Mui Cay Sao, Mui Da Chong) were much lower with about 0.013, 0.034, and 0.043 kg/m² respectively (Fig. 5).

The analysis showed that macroplastic density was not related to the quantity. The beaches with the highest level of

macroplastic density were not those with the highest quantity of macroplastic.

3.2 Sources, size, and types of microplastic

Of 505 macroplastic items collected, the majority were single-use plastics such as plastic bags (192 items), plastic straws and spoons (41 items), and plastic cups (34 items). Other single-use plastics such as Styrofoam, plastic bottles, food packaging and containers, and cotton swabs were also found on the beaches, which were 38, 19, 35, and 4 items respectively. The study showed that single-use plastic accounted for more than 82% of total debris collected. Other macroplastic included plastic fragments, PVC fishing float foams, ropes which accounted for about 18%. Most of the macroplastic came from tourists and



Fig. 6. Plastic waste from marine aquaculture activity

Rys. 6. Odpady z tworzyw sztucznych pochodzące z akwakultury morskiej

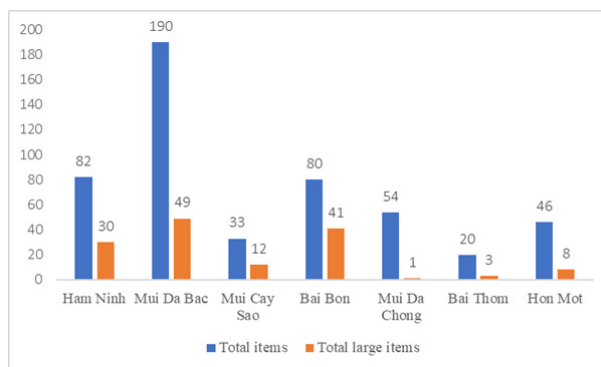


Fig. 7. The total macro-plastic items sampled at the study area

Rys. 7. Łączna liczba próbek makroplastiku pobranych na badanym obszarze

terrestrial sources such as streams, canals, or rivers. Plastic debris because of illegal dumping and uncontrolled littering was thrown into the current drainage system on the island under the influence of seasonal wind and rain. This debris eventually ended up in the ocean. Furthermore, the semi-structured interviews showed that there was no waste collection infrastructure and service available in place, forcing the local people to dispose of solid waste into the ocean (see Table 4).

Those living in areas near the sea or in remote areas with limited access to waste collection services tended to dispose of wastes in open environments. The wastes were then blown into the ocean by seasonal wind or rain. The other main source came from tourism activities. Up to date, 404 hotels, resorts, and hostels were operated with about 28,172 rooms. Despite dust bins available around restaurants located on islands, tourists occasionally dropped plastic bags or empty drinking bottles into the ocean. In camping sites, tourists did not collect their waste when they left the sites. The waste eventually ended up in the ocean. In addition, solid waste management, especially plastic waste was not adequately considered during the construction of hotels and resorts along the beaches, creating a significant pollution source. Farm operators did not have adequate knowledge of marine plastic waste management. Uncontrolled disposal of plastic products caused contributed to the beach pollution in addition to plastic fragments from their aquaculture and fishing such as plastic fragments from fishing gears (fishing nets, squid hook) (Fig. 6).

Plastic waste accumulated on the beaches also came from the ocean under the influence of seasonal tides, waves, and winds. The results showed that there were 144 large size items (more than 30 cm in length) which accounted for 28.5% of total waste collected. Mui Da Bac, Bai Bon, and Ham Ninh received the highest number of large items being 49, 41, and 30 items respectively (Fig. 7).

The size in length of large items ranged between 39.875 ± 4.286 cm (Hon Mot beach) and 60 ± 3.596 cm (Ham Ninh beach) (see Table 5). The average size was about 49.397 ± 3.971 cm. Mostly the large items were single-use plastic bags. For normal macroplastic items, their size ranged between 7.388 ± 1.173 cm (at Bai Thom) and 23.547 ± 6.223 cm (at Mui Da Chong). The average size of macroplastic items was about 14.932 ± 1.846 cm. They were plastic fragments, single-use plastics such as straws, spoons, cups, and plastic bottles and caps (Table 5).

In terms of material types, most macroplastic were HDPE (accounted for 34.85%), mostly used for single-use plastic bags and in plastic fragments. Other material types were PET/PE/PETE and PP being 27.92 and 23.17% respectively. They were the main materials that were used to produce single-use plastic products such as spoons, straws, cups, plastic bottles, and caps. The number of macroplastic found in PS was about 10.30% (Table 6).

4. Discussion

4.1 Marine plastic debris and current waste management in Phu Quoc island

The study reveals that despite various policies and instructions on properly managing waste issued by Phu Quoc People Committee, plastic waste was still found with high density along small streams and canals. The waste also ended up in the ocean beyond control. The findings in entirety in accordance with recommendations provided by WWF in 2018. However, the study presented levels and quantity of marine plastic debris disposed on the beaches as well as pollution sources. To avoid this problem, waste collection infrastructure and service should be established particularly in populated areas, remote areas, along the canals, and streams. Besides, local awareness of the proper disposal of wastes should also

Tab. 5. Size distribution (in length) of macro-plastic at study areas
 Tab. 5. Rozkład wielkości (pod względem długości) makroplastiku na badanych obszarach

No.	Beaches	Large items		Macroplastic items	
		Mean	SE	Mean	SE
1	Ham Ninh	60.000	3.596	14.731	0.990
2	Mui Da Bac	53.888	2.507	12.467	0.527
3	Mui Cay Sao	56.083	5.547	14.443	1.499
4	Bai Bon	46.034	2.092	17.638	1.311
5	Mui Da Chong	-	-	23.547	6.223
6	Bai Thom	40.500	5.795	7.388	1.173
7	Hon Mot	39.875	4.286	14.311	1.200

Tab. 6. Material types of Plastic waste. Note: HN – Ham Ninh, MDB – Mui Da Bac, MCS – Mui Cay Sao, BB – Bai Bon, MDC – Mui Da Chong, BT – Bai Thom, HM – Hon Mot

Tab. 6. Rodzaje skład materiałowy odpadów z tworzyw sztucznych

No.	Material type	Number of items							Total	%
		HN	MDB	MCS	BB	MDC	BT	HM		
1	PET/ PE/ PETE	38	45	12	26	10	4	6	141	27.92
2	HDPE	23	63	10	32	19	9	20	176	34.85
3	PVC	0	0	0	0	0	0	0	0	0.00
4	LDPE/ LLDPE	3	6	2	2	0	0	1	14	2.77
5	PP	17	50	3	12	15	5	15	117	23.17
6	PS	0	26	6	8	8	2	2	52	10.30
7	Other	1	0	0	0	2	0	2	5	0.99
Total									100	

be improved. The residents should be involved in collecting waste along streams and canals and stop the disposal of waste into the marine environment. Law enforcement should also be strengthened along rivers and canal corridors. An additional collection of waste along the rivers and channels, dredging are needed to facilitate the flow in streams and rivers such as Ong Tri, Cua Lap canals, Cao stream, Ben Tram stream, Da Ban stream, Somaco canal, Cong Ban canal, Duong Dong 1 Secondary School canal, Sasco parking area, Xeo stream canal, Ba Phong bridge canal, Ba Keo bridge canal. Monitoring station systems should also be established in order to measure leakage of plastic waste at streams and canals. Finally, there is a need for raising local awareness and social behavior on waste separation at sources and discouraging the use of single-use plastic products on a daily activity basis.

4.2 The limitation of the study

The study presented the information in relation to marine plastic debris, quantity, and pollution sources. However, this study did not undertake an analysis in detail of how the waste has affected the biodiversity and environment in the region. If opportunities arise, marine environment and water quality

should be tested and analyzed to understand pollution levels, as well as marine fauna and flora species, which should also be monitored to understand pollution effects on their lives.

5. Conclusion

In investigating the current marine plastic debris status in Phu Quoc MPA, we found that the beaches of Phu Quoc MPA were heavily polluted with marine plastic debris. The debris came from different sources. The distribution of microplastic was different from beach to beach. Most of the microplastic found were single-use plastic with the most common of plastic bags in HDPE. The current policies and instructions should be amended or revised together with strengthened law enforcement in order to deal with marine plastic pollution towards sustainable seagrass management and conservation.

6. Acknowledgments

The authors would like to thank the ASEANO Research Grant Competition for the grant. The authors would also like to extend our thanks to the Coasts and People organization for proofreading and editing.

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Odpady z tworzyw sztucznych w morskim obszarze chronionym Phu Quoc w Wietnamie: aktualny stan i metody łagodzenia skutków

Zanieczyszczenie morza tworzywami sztucznymi powoduje niekorzystne skutki dla globalnego środowiska i ekosystemów morskich, szczególnie w morskich obszarach chronionych. Jednak niewiele wiadomo na temat wpływu plastikowych odpadów morskich na funkcjonowanie ekosystemów morskich, dobrostan ludzi, społeczeństwo i gospodarkę. Wybraliśmy Morski Obszar Chroniony Phu Quoc (Phu Quoc MPA), aby uzyskać wgląd w aktualne morskie odpady plastikowe jako pierwszy krok w kierunku zrozumienia ich wpływu na środowisko i różnorodność biologiczną w regionie. W badaniu tym zastosowano analizę danych wtórnych, częściowo ustrukturyzowane wywiady, pomiary terenowe i metodę transektu linii kwadratowej w dążeniu określenia wpływu czynników. Badania wykazują, że morskie odpady plastikowe usuwane w Phu Quoc MPA pochodziły z różnych źródeł, w tym z rzek, strumieni, kanałów, dostawców usług turystycznych i obszarów rozwoju akwakultury morskiej. Obfitość makroplastiku na plażach wynosiła w przybliżeniu od 1,109 do 0,248 sztuk/m² (co odpowiada 0,082 ± 0,021 kg/m²). Większość makroplastiku to tworzywa sztuczne jednorazowego użytku, które stanowiły ponad 82%. Średni rozmiar wynosił około 14,932 ± 1,846 cm dla przedmiotów mniejszych niż 30 cm. Pozostałe to torby foliowe HDPE i odpady z tworzyw sztucznych. Należy powstrzymać wyrzucanie makroplastiku i mikroplastiku, aby zachęcić do zrównoważonego gospodarowania odpadami w regionie.

Słowa kluczowe: makroplastik, mikroplastik, morski obszar chroniony Phu Quoc, Wietnam, zalecenia polityczne, tworzywa sztuczne jednorazowego użytku