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Accumulation rate and sources of plastic marine litter at nesting grounds of green turtles on the North Island of Qilianyu, Xisha Islands, South China Sea

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ABSTRACT

In this study, the accumulation rate of plastic litter was investigated by sampling quadrats placed on the North Island of Qilianyu, and the composition was analyzed and identified to determine its source. The results showed that the annual average accumulation rate of plastic litter on North Island was 0.64 ± 0.32 pieces·m^{-2}·month^{-1}, with a mass accumulation rate of 11.30 ± 7.73 g·m^{-2}·month^{-1}. The accumulation rate of plastic litter was mainly influenced by wind speed and direction, with higher accumulation rates occurring during the southwest monsoon season and tropical cyclones. ATR-FTIR analysis indicated that polyethylene (44 %) and polypropylene (41 %) were the most abundant types of polymers. This study reveals the current status of plastic litter pollution in green turtle nesting grounds on North Island in Qilianyu, which can be used as a reference for management strategies that mitigate plastic litter pollution.

1. Introduction

Sea turtles play a crucial role in maintaining the health and stability of marine ecosystems (Bouchard and Bjorndal, 2000) and serve as important indicator species for marine environmental monitoring (Camacho et al., 2014). Therefore, they are considered “flagship species” and “umbrella species” for international marine conservation efforts (Hamann et al., 2010; Lin et al., 2023). However, owing to large-scale illegal trade and habitat loss, the number of sea turtles in China has dramatically declined, and almost all nesting grounds along the Chinese coast have disappeared (Lin et al., 2021). The remaining nesting ground in mainland China, the Guangdong Huidong Sea Turtle National Nature Reserve, has only had one wild green turtle nesting activity since 2018 (Mou et al., 2013; Wei, 2016). However, sea turtle nesting has been recorded on multiple islands on the Xisha Islands. The number of green turtle nests recorded annually in Qilianyu of the Xisha Islands has exceeded 100, and the number of turtle nests on the North Island has been the highest in recent years (Wang et al., 2019; Zhang et al., 2024). Furthermore, recent studies have found that the green turtle population on the Xisha Islands has a unique genetic composition, representing a new geographic population and an independent conservation management unit (Gaillard et al., 2020; Song et al., 2022). Therefore, protecting this unique turtle population and its nesting grounds is crucial for the conservation of sea turtle populations in China.

The accumulation of plastic litter in nesting grounds is one of the main threats to sea turtle nesting and hatching, and its effect on sea turtle health and reproduction has become a popular topic of global sea turtle conservation (Laist, 1997). Studies have shown that plastic litter in sea turtle nesting grounds not only disrupts the nest site selection of female turtles, leading to nesting failures or changes in nesting locations (Hays and Speakman, 1993; Laurance et al., 2008; Bourgeois et al., 2009; Witherington et al., 2011), but also hinders the pathway of newly hatched turtles crawling to the shoreline, increasing their chances of predation (Tomillo et al., 2010; Triessnig et al., 2012; Burger and Gochfeld, 2014). Additionally, marine litter accumulation can alter the incubation temperature inside the nests, thereby affecting the sex ratio

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of sea turtles and their population structure (Carson et al., 2011).

According to the China Marine Ecological Environment Status Report (2019), the average amount of plastic litter in China is 280,043 pieces per square kilometer, with plastic litter accounting for 81.7 % of the total. The main types of plastic litter include foam, cigarette filters, bottles, and bags. Zhao et al. (2016) conducted a survey of litter at 24 beaches in China and found that plastic litter accounted for the highest proportion of all types of litter. A study investigating the current status of plastic litter in the nesting grounds of green turtles in Qilianyu found that the litter types mainly included plastic, metal, and glass, with plastic litter being the most abundant, accounting for a higher proportion compared to other sea turtle nesting grounds (Zhang et al., 2020). However, research on the distribution patterns and sources of plastic litter during different seasons in the nesting grounds of green turtles in the Qilianyu region of the Xisha Islands is still lacking.

Therefore, this study conducted a comprehensive field investigation of the seasonal distribution patterns and sources of plastic pollution in the Northern Island of Qilianyu in the Xisha Islands. Our main objectives were to (1) explore the accumulation rate of plastic marine litter at the nesting grounds of green turtles in the North Island of Qilianyu and (2) identify the main sources of plastic litter in the North Island, as well as provide recommendations to prevent and control these pollutants from the source.

2. Materials and methods

2.1. Study area

The Qilianyu of the Xisha Islands (16°55′-17°00′N, 112°12′-112°21′E) are located in the northeastern part of the Xisha Islands in the South China Sea. The North Island, also known as Changzhi, is located in the middle of Qilianyu. It is over 1500 m long and approximately 290 m wide, with an area of approximately 0.4 km^2 (Fig. 1). North Island is the largest island in Qilianyu and has the largest number of green turtle nests each year (Wang et al., 2011).

During the southwest monsoon season, which is the peak season for sea turtle nesting, the prevailing wind is southwest with an average wind force of 4–6 m/s. During the northeast monsoon season, the prevailing wind is northeast with an average wind force of 6–9 m/s. During tropical cyclones, the prevailing wind direction is southwest, with an average wind force of 6–7 (Ye, 1996).

2.2. Sample collection

Because of the North Island is long and narrow, with a northwest-southeast orientation. In order to investigate the accumulation rate of litter on the beaches of different directions in North Island, three sample points were randomly selected on the south, southwest and north coast of the North Island according to the methods provided in the “Technical Regulations for Monitoring and Evaluation of Marine Litter” issued by the Ecological and Environmental Protection Department of the State Oceanic Administration. And at each sample point, three repeated quadrates are set up, Fig. 2. Each quadrate is vertically divided into 4 transect zones (50 m × 1 m), the first transect is the high water line, the fourth is the vegetation line, and the second and third transect zones are set between the high water line and the vegetation line (the distance between the transect zones is 4–14 m, divided by the width of the beach).

The two sampling times were during the southwest monsoon period in July 2021 and the northeast monsoon period in October 2021. Prior to the survey, visible litter fragments (size ≧1 cm) within the quadrats were completely cleared. Sampling time were set at after 1 month, all the plastic litter (size ≧1 cm) in the quadrats will be collected. The accumulation rate of litter was measured in terms of pieces·m^{-2}·$month^{-1}$ and g·m^{-2}·$month^{-1}$.

Because of the frequent occurrence of tropical cyclones during the southwest monsoon period in the Xisha Islands, we collected plastic litter once after a tropical cyclone (Typhoon Koguma, June 12–13, 2021) in June 2021 to compare plastic litter accumulation under extreme weather conditions. Similarly, the litter in the sample was cleaned before the typhoon came, and the litter (size ≧1 cm) was collected 7 days later, and then the conversion of data units was carried out.

2.3. Plastic litter sorting

The collected plastic litter was classified into different categories based on its characteristics and functions. The main categories include

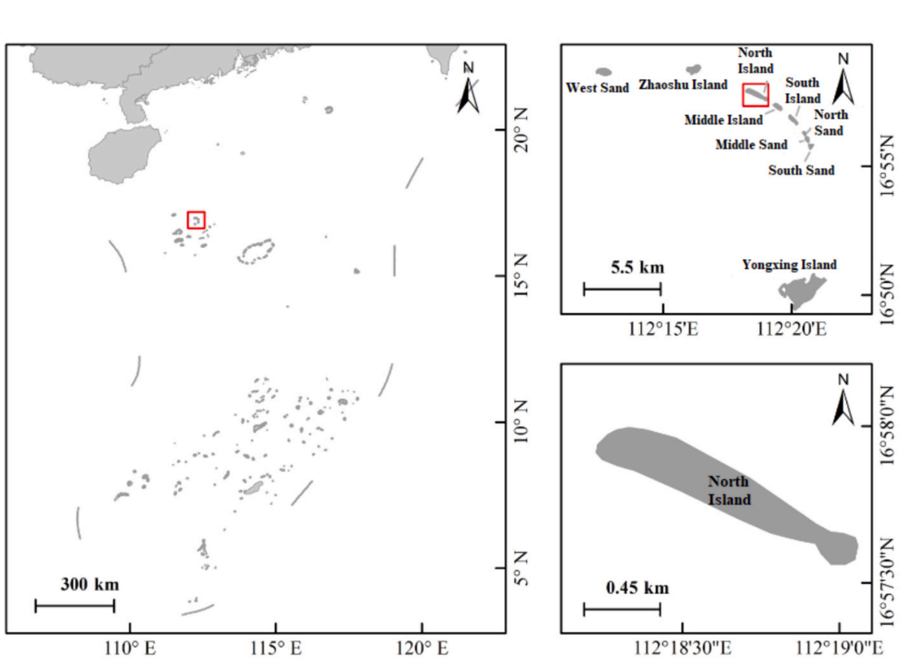

Fig. 1. Study area.

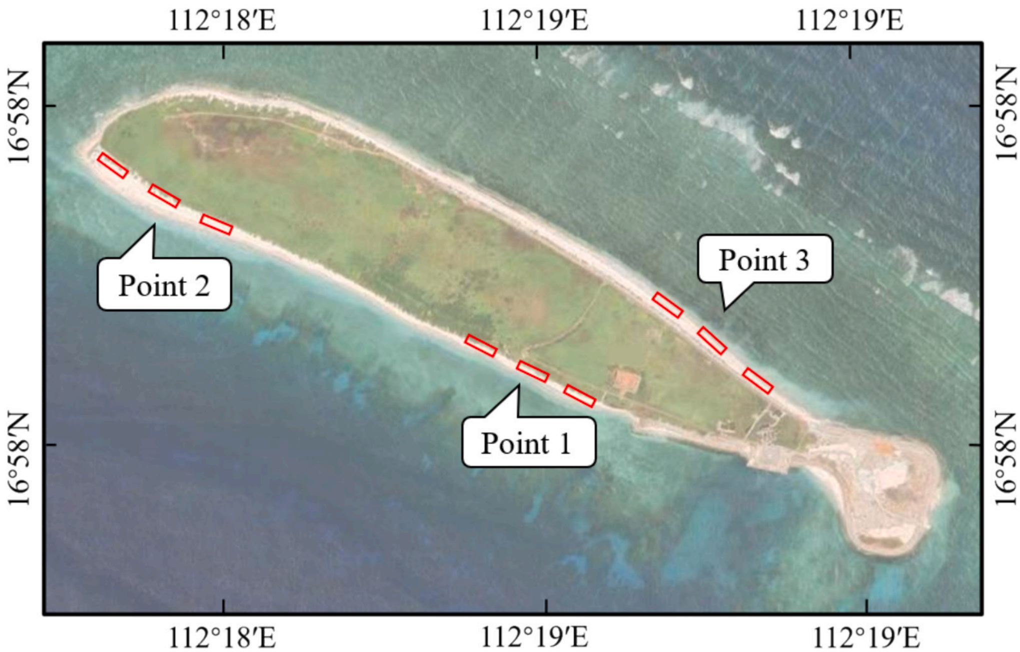

Fig. 2. Three sample points on North Island, Qilianyu.

white foam, floats, fishing nets/ropes, plastic bags, beverage bottles/caps, daily household items, disposable products, and unidentifiable plastics (Zhao et al., 2020).

The white foam category mainly consisted of common foam litter, whereas the floats include fishing floats and buoys, which are commonly found in the fishing industry. Plastic bags primarily referred to common plastic and food-packaging bags. Daily household items included cosmetic bottles, slippers, lighters, toothbrushes, and unidentifiable plastics. Disposable products included cups, straws, and masks. Unidentifiable plastics included fragmented plastic litter in the size range of >10 cm with unidentified sources.

The sources of plastic litter were analyzed using the investigation and statistical methods of the Northwest Pacific Action Plan (NOWPAP), which categorizes sources into five major categories: human coastal activities, shipping/fishing activities, smoking-related items, medical/sanitary items, and other litter (Guo et al., 2014; Mo et al., 2018). For litter with visible text, the country of origin was determined by identifying the origin information on the packaging (Sul et al., 2011).

Since these green turtles nest predominantly during the southwest monsoon season, litter collected during this season was used for determine its color, source, and composition.

2.4. Identification of plastic properties

We selected a representative subset of plastics from each group, and their surface structures were tested to determine the polymer type using a Fourier transform infrared spectrometer (IRTracer-100, SHIMADZU, Kyoto, Japan). Plastic samples were placed in the sample area, and during data acquisition, the ATR imaging attachment was placed in direct contact with the plastics on the filter membrane. The detector spectral range was 600–4000 cm^{-1}, coadding 16 scans at a resolution of 8 cm^{-1}. The spectra were processed using the LabSolutions IR software and compared with the IR polymer spectra library. The composition of the plastic was determined to be the same as that of the corresponding polymer spectrum only when the degree of similarity was >70 %.

2.5. Data analysis

Statistical analysis was conducted using SPSS 16.0 statistical software. Prior to the statistical analysis, all data were tested for normal distribution and homogeneity of variance. One-way analysis of variance (ANOVA) with multiple comparison tests was used to analyze the differences in plastic litter accumulation rates among the points. The relevant data in the study are presented as the mean ± standard deviation (SD), and a significance level of $P < 0.05$ was considered statistically significant (two-tailed test). The litter accumulation rates in the three points during the southwest and northeast monsoon periods were summed and averaged to estimate the annual litter accumulation rate for each point.

3. Results

3.1. Accumulation rate of plastic litter on the North Island

The average accumulation rates of plastic litter on the North Island of Qilianyu are 0.64 ± 0.32 pieces·m^{-2}·$month^{-1}$ in quantity and 11.30 ± 7.73 g·m^{-2}·$month^{-1}$ in mass. Compared to the average accumulation rates of plastic litter on Chinese beaches, the accumulation rates on the North Island of Qilianyu were relatively high (Table 1).

The average accumulation rates of plastic litter on the south coast, southwest corner, and north coast were as follows: 0.63 ± 0.03 pieces·m^{-2}·$month^{-1}$ ($n = 3$), 0.70 ± 0.08 pieces·m^{-2}·$month^{-1}$ ($n = 3$), and 0.47 ± 0.05 pieces·m^{-2}·$month^{-1}$ (n = 3), respectively. The average accumulation rates of plastic litter in terms of mass were 12.14 ± 0.49

Table 1
Comparison of the accumulation rate of plastic litter between North Island and the average value of domestic sea area.

Study area	Accumulation rate of plastic litter quantity (pieces·m^{-2}·$month^{-1}$)	Accumulation rate of plastic litter mass (g·m^{-2}·$month^{-1}$)	References
North Island	0.64 ± 0.32	11.30 ± 7.73	This study
Average value of Chinese beaches	0.58	5.2	2020 Report on the Ecological and Environmental Status of China's Marine Ecosystems

g·m^{-2}·month^{-1} (n = 3), 12.82 ± 1.14 g·m^{-2}·month^{-1} (n = 3), and 8.94 ± 1.50 g·m^{-2}·month^{-1} (n = 3), respectively (Fig. 3). The results indicated that the southwest corner had the highest accumulation of plastic litter in both quantity and mass throughout the year, which is consistent with the findings of Zhang et al. (2020).

3.2. *Effects of monsoon on the accumulation rate of plastic litter*

In tropical cyclones, the overall average accumulation rate of plastic litter quantity (0.57 pieces·m^{-2}·month^{-1}) on the North Island was the same as that of the southwest monsoon and higher than that of the northeast monsoon. However, the plastic litter accumulation rate was higher during tropical cyclones than under normal southwest monsoon and northeast monsoon weather conditions. Therefore, tropical cyclones transported heavier plastic litter to the shoreline, as shown in Fig. 4.

The accumulation rates of plastic litter vary across different monsoon seasons on the North Island. During the southwest monsoon period, the accumulation rate of plastic litter was highest on the southwest coast of North Island, with a value of 0.93 pieces·m^{-2}·month^{-1}, followed by the south coast with a value of 0.82 pieces·m^{-2}·month^{-1}. These rates were significantly higher than those on the north coast of North Island ($F(2, 6) = 28.751$, $P = 0.001$). However, during the northeast monsoon period, the accumulation rate of plastic litter on the north coast was 0.58 pieces·m^{-2}·month^{-1}, which was significantly higher than that on the south and southwest coasts ($F(2, 6) = 30.537$, $P = 0.001$), Fig. 5.

3.3. *Type and color of plastic litter on the beaches of North Island*

The results showed that the highest proportion was unidentifiable plastics (29.08 %), followed by beverage bottles/caps (24.42 %) (Fig. 6). The most common color of plastic litter was white (50.33 %), including both transparent and white particles. Among these color categories, white foam and bottles were the most common. Multi-colored plastic litter, such as blue, yellow, black, green, red, and other colors, accounted for approximately 49.67 % (Fig. 7). Overall, the plastic litter on the beaches of the North Island in Qilianyu was mainly white, transparent, blue, and yellow, which is similar to the findings of Fang et al. (2021) on Ganquan and Quanfu Island in the same area.

3.4. *Source of plastic litter on the beaches of North Island*

By classifying and counting plastic litter collected from the beaches in North Island, a source inventory (Table S1) of plastic litter was created based on their different sources, uses, and characteristics, such as shape, color, and composition.

The sources of plastic litter were classified, and the results showed that the highest proportion of garbage (65.4 %) was generated by human coastal activities. The second highest proportion of garbage was generated from shipping and fishing activities, with proportions of 24.7 % (Fig. 8). This is similar to the results obtained by Zhang et al. (2020) for the sources of beach debris on the North Island.

ATR-FTIR analysis indicated that the main components of plastic litter collected from the North Island beach area were PP, PE, PS, PET, PU, PVC, and EVA, among which polyethylene (44 %) and polypropylene (41 %) were the most abundant polymers (Table S1).

4. Discussion

The accumulation rate of plastic litter on the North Island of Qilianyu was higher than that in other sea areas of China. This is mainly because of the high plastic litter discharge and large import volume in Southeast Asia, resulting in a large amount of plastic flowing into the ocean from rivers, making the South China Sea a heavily polluted area with marine plastic litter (Liu, 2020). On the other hand, the high accumulation rate is related to the geographical location of the study site. The Xisha Islands are located in the South China Sea and surrounded by densely populated countries that may introduce more plastic pollutants. Wang et al. (2012) pointed out that there is anticyclonic circulation in the Xisha area, which causes surface seawater around the South China Sea to flow through the Xisha area, thus bringing plastic litter discharged by neighboring

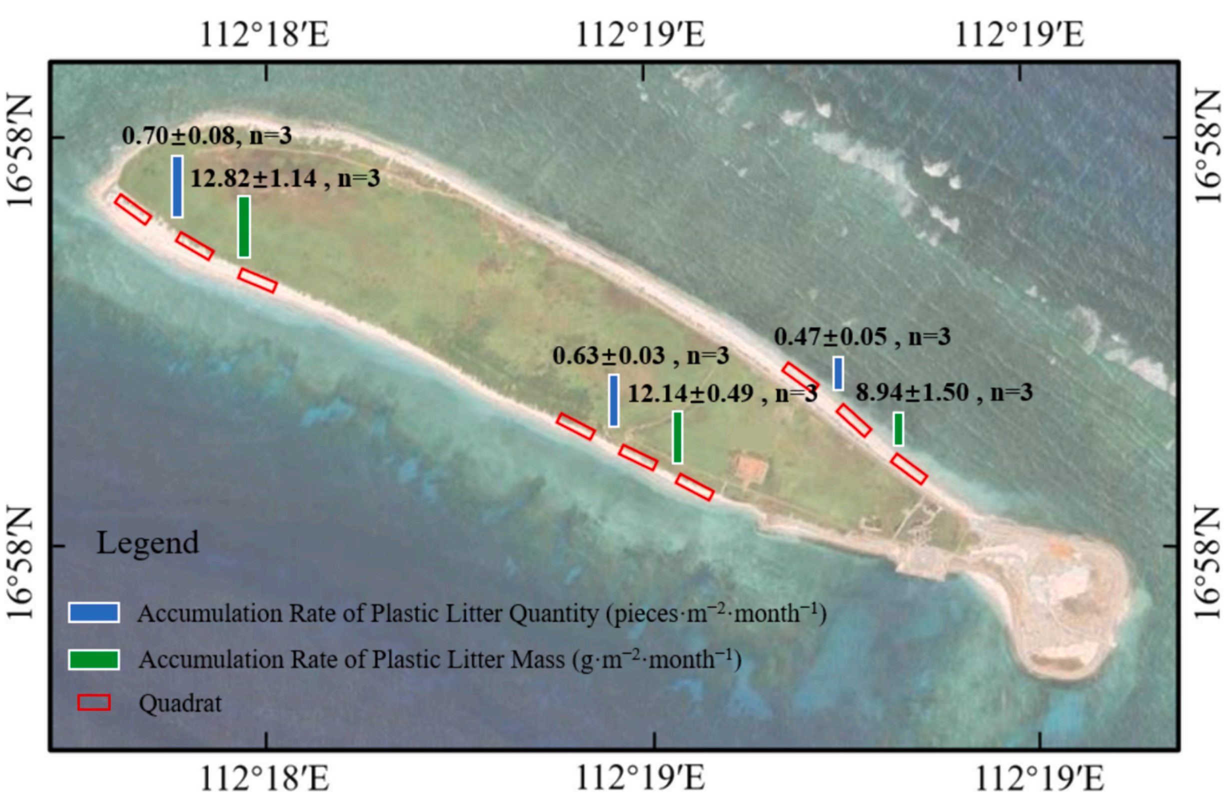

Fig. 3. Annual cumulative rate of beach plastic litter in three points on North Island, Qilianyu.

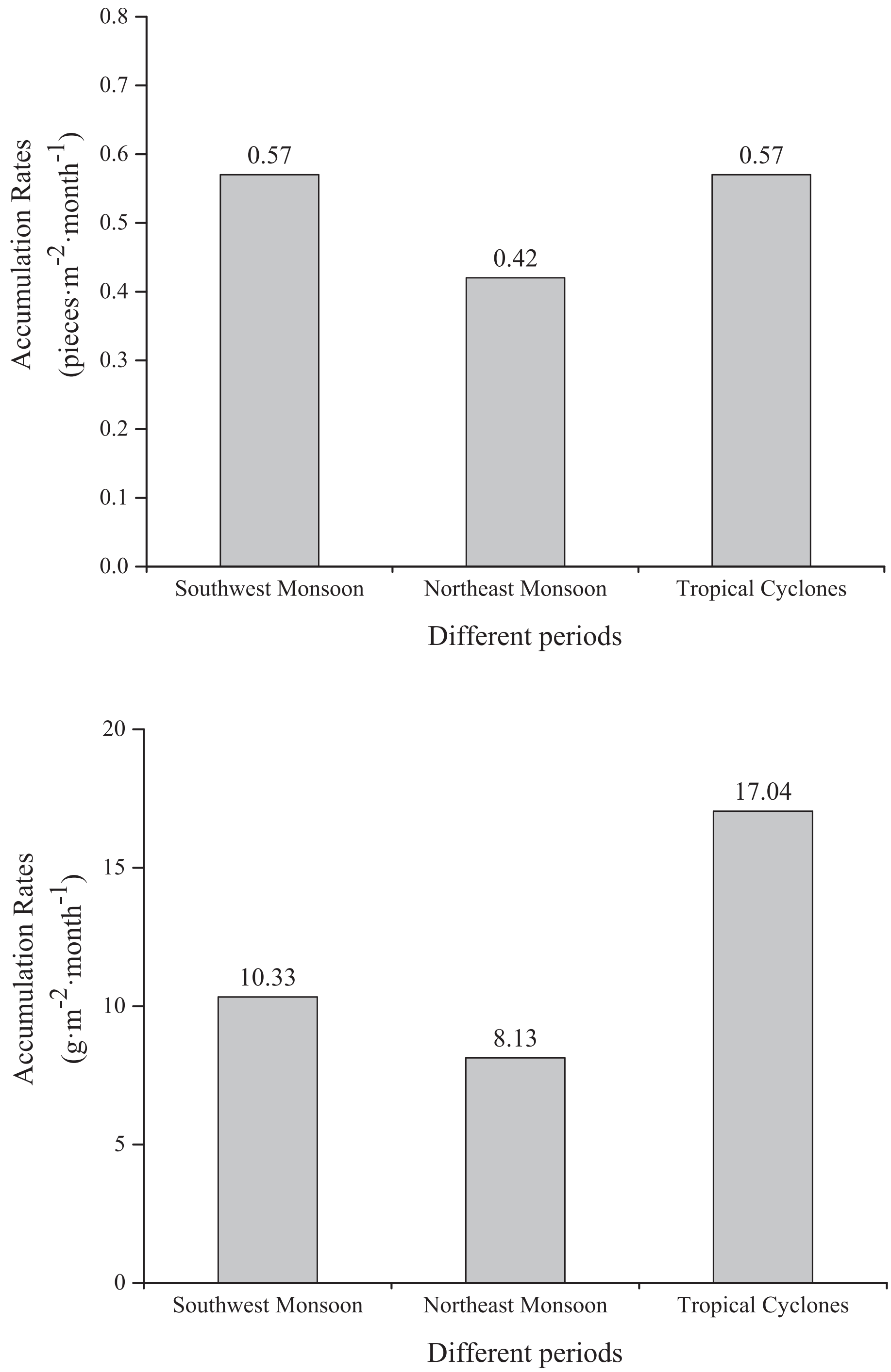

Fig. 4. Accumulation rate of plastic litter in different periods on North Island.

countries of the South China Sea. Zhang et al. (2020) found that 82 % of the plastic litter on the beaches of the North Island in Qilianyu came from Southeast Asian countries such as Vietnam and the Philippines.

The accumulation rate of marine plastic litter is influenced by the direction and intensity of the monsoon winds (Rajakumar et al., 2024). The average wind speed during tropical cyclones was greater than that during the southwest monsoon stronger wind forces during monsoon climate result in heavier marine plastic litter. However, as only one tropical cyclones was encountered during the experiment, more monitoring is recommended in the future to demonstrate the impact of tropical low pressure weather on the accumulation rate of plastic on beaches.

During the southwest monsoon, the beach at the southwest corner of North Island had the highest litter accumulation rate, which is consistent with the findings of Zhang et al. (2020). However, green turtles nest predominantly during the southwest monsoon season and the southwest corner had the highest frequency of sea turtle nesting on North Island (Zhang et al., 2020). Therefore, the accumulation of plastic litter may affect the nesting of green turtles on the North Island. Regular beach cleaning is an effective strategy for improving sea turtle nesting grounds (Fujisaki and Lamont, 2016). Zhang et al. (2024) showed that microplastics in beach sediments on North Island were broken from large plastics. Therefore, beaches with higher litter accumulation rates should increase their beach cleaning frequency, particularly during the peak

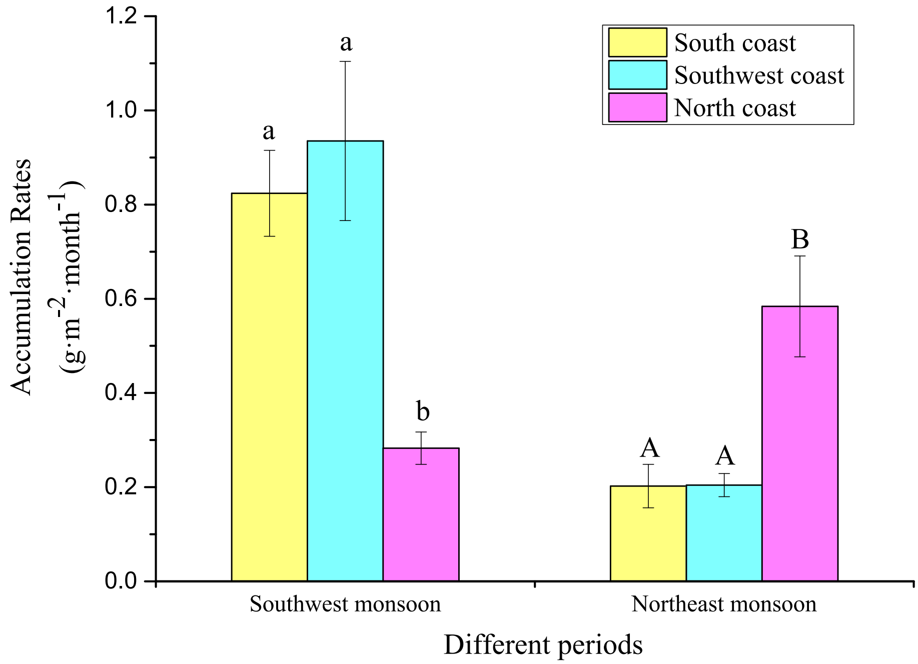

Fig. 5. The cumulative rate of plastic litter on different coasts of North Island during different monsoon periods. Different letters in the figure indicate significant differences at the $P < 0.05$ level.

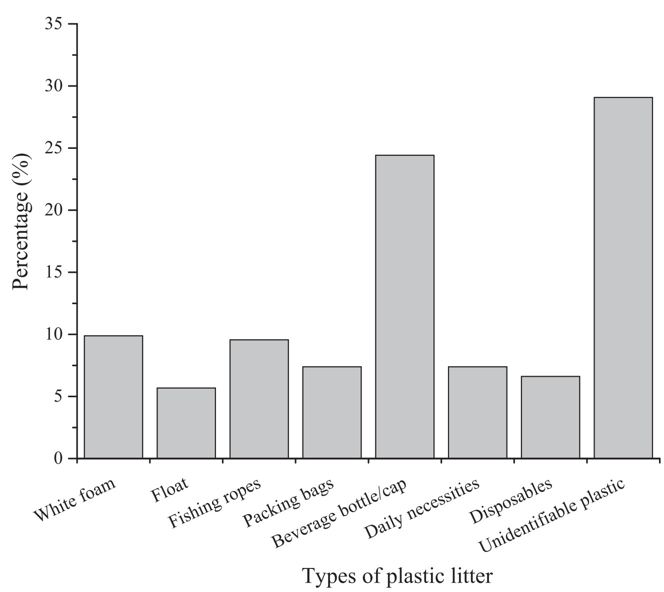

Fig. 6. Composition types and proportions of plastic litter.

nesting period of sea turtles and under tropical cyclonic conditions. We recommend increasing beach cleaning frequency from once a week to every 2–3 d, and increasing the intensity and frequency of litter cleaning during the peak nesting period of sea turtles in areas of litter accumulation.

According to the analysis of plastic litter composition, the proportion of unidentifiable plastics was the highest, followed by beverage bottles/caps. Because of the stable nature of plastic bottles/caps, they are not easily broken during long-distance transportation, whereas most plastic litter is broken into unidentifiable plastic under the action of waves and ultraviolet rays during long-distance transportation, and they also gradually loses its color becoming transparent and white (Vidyasakar et al., 2018; Tan et al., 2020). Notably, the high proportion of transparent and white plastics in plastic litter in this study indicates that it has been in the ocean and exposed to the environment for a long time before reaching the beaches of the North Island. In addition, foam litter accounted for a relatively high proportion, similar to the continuous inventory survey results of Ganquan Island and Quanfu Island of the Xisha Islands (Fang et al., 2021). This is because polystyrene foam has a low density, making it more likely to float on the sea surface and strand on beaches (Kaiser, 2010). Through field investigations and consultations with fishermen, we found that there were only a few fishing and aquaculture activities on North Island and strict local implementation of litter classification, treatment, and recycling policies, so there was basically no pollution caused by local plastic litter. Plastic litter is mainly transported over long distances by ocean currents.

Beaches serve as both sources and sinks of marine plastic litter, and the litter is accumulating so fast that beaches need cleaning multiple times a week to help with sea turtle nesting. However, because of plastic litter on North Island beaches is mainly transported from surrounding countries through long-distance ocean transport and accumulates on the beaches in this area. Therefore, in addition to regular cleaning, it is necessary to strengthen plastic litter management at the source, enhance regional cooperation, and reduce the generation and discharge of marine plastic litter (Zhu et al., 2019). Countries should strengthen policy planning, strictly comply with the United Nations Convention on the Law of the Sea, and formulate practical plastic bans to address plastic pollution from production sources, thus fulfilling their obligation to protect and preserve the marine environment. At the same time, from the public perspective, it is necessary to strengthen public education and awareness, transform public mindsets and concepts, and encourage public participation in governance.

5. Conclusions

The study found that the average accumulation rate of plastic litter on North Island of Qilianyu throughout the year was 0.64 ± 0.32 pieces·m^{-2}·month^{-1}, with a mass accumulation rate of 11.30 ± 7.73 g·m^{-2}·month^{-1}. Notably, higher accumulation rates were observed during the southwest monsoon and tropical cyclones. The most common color of plastic litter was white (50.33 %), which included both transparent and white litter, implying that these plastics have been

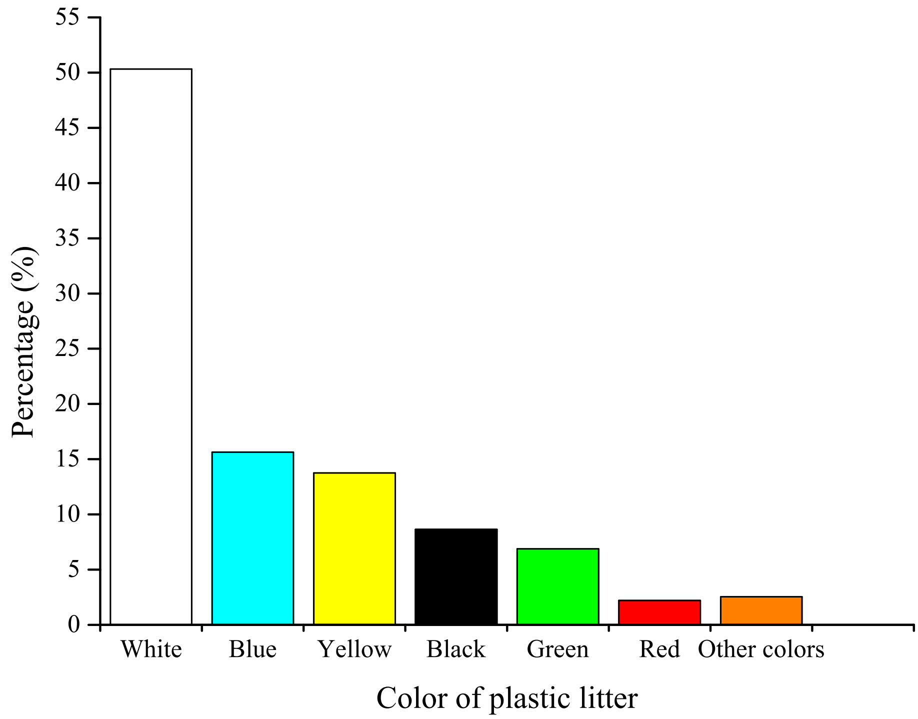

Fig. 7. Colors and proportions of plastic litter. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

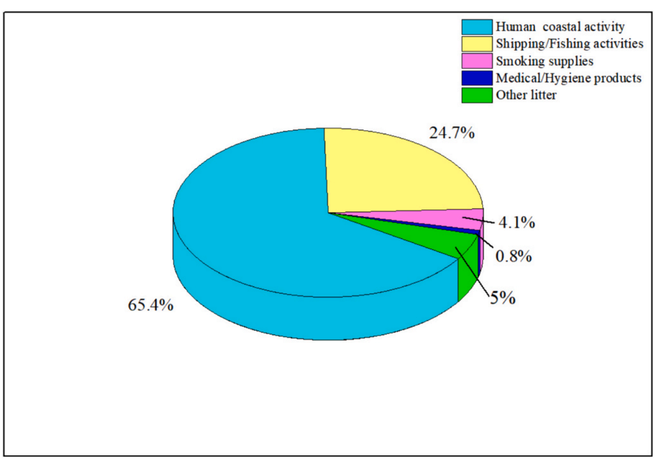

Fig. 8. Classification statistics of plastic litter sources.

deteriorating for a long period and originated from non-localized sources. Plastic litter mainly originated from plastic bottles/caps generated by human coastal activities, followed by floating fishing nets generated by aquaculture. Increasing the frequency of plastic litter cleaning during seasons with high accumulation rates and strengthening regional cooperation in the South China Sea are recommended to promote the governance of marine litter worldwide.

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CRediT authorship contribution statement

Ting Zhang: Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Yongkang Jiang:** Writing – original draft, Methodology, Formal analysis. **Deqin Li:** Writing – original draft, Investigation. **Chenglong Zhang:** Writing – review & editing, Formal analysis. **Yunteng Liu:** Writing – review & editing, Formal analysis. **Yupei Li:** Writing – review & editing. **Yangfei Yu:** Methodology, Investigation. **Jichao Wang:** Formal analysis. **Hai-Tao Shi:** Writing – review & editing. **Liu Lin:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare no conflicts of interests.

Data availability

No data was used for the research described in the article.

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References

Bouchard, S.S., Bjorndal, K.A., 2000. Sea turtles as biological transporters of nutrients and energy from marine to terrestrial ecosystems. Ecology 81, 2305–2313.
Bourgeois, S., Gilot-Fromont, E., Viallefont, A., Boussamba, F., Deem, S.L., 2009. Influence of artifficial lights, logs and erosion on leatherback sea turtle hatchling orientation at Pongara National Park. Gabon. Biological Conservation 142, 85–93.
Burger, J., Gochfeld, M., 2014. Factors affffecting locomotion in Olive Ridley (*Lepidochelys olivecea*) hatchlings crawling to the sea at Ostional Beach. Costa Rica. Chelonia Conservation and Biology 13, 182–190.
Camacho, M., Orós, J., Henríquez-Hernández, L.A., Valerón, P.F., Boada, L.D., Zaccaroni, A., Zumbado, M.L., Luzardo, O.P., 2014. Influence of the rehabilitation of injured loggerhead turtles (*Caretta caretta*) on their blood levels of environmental organic pollutants and elements. Science of the total environment 487, 436–442.

Carson, H.S., Colbert, S.L., Kaylor, M.J., McDermid, K.J., 2011. Small plastic debris changes water movement and heat transfer through beach sediment. Marine Pollution Bulletin 62, 1708–1713.
Fang, Z., Tan, F., Yang, H.Q., Xu, H.L., Xu, X.R., Li, H.X., 2021. Distribution characteristics of plastic debris and microplastics on Ganquan Island and Quanfu Island in Xisha waters. J. Trop. Oceanogr. 40 (05), 123–133.
Fujisaki, I., Lamont, M.M., 2016. The effects of large beach debris on nesting sea turtles. J. Exp. Mar. Biol. Ecol. 482, 33–37.
Gaillard, D., Yeh, F.C., Lin, L., Chen, H.Q., Zhang, T., Luo, S.J., Shi, H.T., 2020. Lost at sea: determining geographic origins of illegally traded green sea turtles (*Chelonia mydas*) rescued on Hainan Island. China. Wildlife Research 48 (1), 55–63.
Guo, F., Li, Z.E., Qin, Y.T., Fan, M.M., 2014. Distribution, composition, and sources analysis of marine debris in Shanghai. Marine Development and Management 9, 110–113.
Hamann, M., Godfrey, M.H., Seminoff, J.A., Arthur, K., Barata, P., Bjorndal, K.A., et al., 2010. Global research priorities for sea turtles: Informing management and conservation in the 21st century. Endangered Species Research 11, 245–269.
Hays, G.C., Speakman, J.R., 1993. Nest placement by loggerhead turtles. Caretta caretta. Animal Behaviour 45, 47–53.
Kaiser, J., 2010. The dirt on ocean garbage patches. Science 328, 1506.
Laist, D., 1997. Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records.
Laurance, W.F., Fay, J.M., Parnell, R.J., Sounguet, G.-P., Formia, A., Lee, M.E., 2008. Does rainforest logging threaten marine turtles? Oryx 42 (2), 246–251.
Lin, L., Li, S., Chen, M., Parham, J.F., Shi, H., 2021. Sea turtle demand in China threatens the survival of wild populations. iScience 24 (6), 102517.
Lin, L., Zhang, T., Shi, H.T., 2023. Sea turtles are ideal flagship species for marine conservation. Chinese Journal of Zoology 58 (4), 481–485.
Liu, R., 2020. Ocean plastic waste treatment in Southeast Asia and China’s participation. International Relations Studies 1, 125–142–159.
Mo, Z.N., Cao, Q.X., Chen, Y., Ning, Q.Y., Li, Yin H., 2018. Investigation and study on marine garbage of typical coastal beaches in Guangxi. Chemical Engineering & Equipment 258 (7), 2951–2958 (In Chinese).
Mou, J.F., Tao, C.H., Ding, X.H., 2013. Preliminary investigation on the species and distribution of sea turtles in China’s coastal waters. Journal of Applied Oceanography 2, 238–242.
Rajakumar, D., De Silva, R.C.L., Amarathunga, A.A.D., 2024. Contamination of buried plastic marine litter on sandy beaches in the West Coast of Sri Lanka. University of Sri Jayewardenepura, Sri Lanka.
Song, J.H., LinBA, Jia Y.Y., Dutton, P., Kang, B., Balazs, G., Liu, M., 2022. New management unit for conservation of the endangered green turtle *Chelonia mydas* at the Xisha (Paracel) Islands, South China Sea. Endanger. Species Res. 47, 145–154.
Sul, J., Friedrich, A., Fillmann, G., 2011. Plastic pollution at a sea turtle conservation area in NE Brazil: contrasting developed and undeveloped beaches. Estuar. Coasts 34 (4), 814–823.
Tan, F., Yang, H., Xu, X., Fang, Z., Xu, H., Shi, Q., Zhang, X., Wang, G., Lin, L., Zhou, S., Huang, L., Li, H., 2020. Microplastic pollution around remote uninhabited coral reefs of Nansha Islands. South China Sea. Sci. Total Environ. 725, 138383.
Tomillo, P.S., Paladino, F.V., Suss, J.S., Spotila, J.R., 2010. Predation of leatherback turtle hatchlings during the crawl to the water. Chelonian Conservation and Biology 9, 18–25.
Triessnig, P., Roetzer, A., Stachowitsch, M., 2012. Beach condition and marine debris: new hurdles for sea turtle hatchling survival. Chelonian Conservation and Biology 11, 68–77.
Vidyasakar, A., Neelavannan, Krishnakumar S., Prabaharan, G., Sathiyabama Alias Priyanka, T., Magesh, N.S., Godson, P.S., Srinivasalu, S., 2018. Macrodebris and microplastic distribution in the beaches of Rameswaram Coral Island, Gulf of Mannar, Southeast coast of India: a first report. Mar. Pollut. Bull. 137, 610–616.
Wang, R., Tang, W., Song, Y., 2011. Analysis of soil environmental quality and characteristics in Xisha Islands. Anhui Agricultural Science 39 (10), 5837–5840.
Wang, D., Shi, M., Nan, F., 2012. Study on the characteristics of tides and residual currents in Xisha Islands. J. Ocean Univ. China 42 (10), 1–9.
Wang, J., Guo, R., Yang, Y., Zhang, Y., Jia, Y.Y., Liu, M., Jin, J., Ji, L., Zhang, J., 2019. Threatened status and conservation recommendations for sea turtles in China. Acta Theriologica Sinica 40 (4), 13.
Wei, W., 2016. Conservation Biology of Green Sea Turtle (*Chelonia mydas*) in the South China Sea. East China Normal University (Doctoral dissertation).
Witherington, Blair, Hirama, Shigetomo, Mosier, Andrea, 2011. Sea turtle response to barriers on their nesting beach. J. Exp. Mar. Biol. Ecol. 401, 1–6.
Ye, J.Z., 1996. Environmental hydrological characteristics of Xisha Islands. Acta Scientiarum Naturalium Universitatis Sunyatseni 35 (S1), 19–25 (In Chinese).
Zhang, T., Lin, L., Jian, L., Wang, Z., Kong, L., Wang, J.C., Shi, H.T., 2020. Investigation of beach litter at the nesting ground of green sea turtles (*Chelonia mydas*) in Qilianyu Islands. Xisha Islands. Chinese Journal of Ecology 39 (07), 2408–2415.
Zhang, T., Li, D.Q., Liu, Y.T., Li, Y.P., Yu, Y.F., An, X.Y., Jiang, Y.K., Wang, J.C., Shi, H.T., Lin, L., 2024. Microplastic distribution characteristics and sources on beaches that serve as the largest nesting ground for green turtles in China. Toxics 12, 109.
Zhao, X., Qi, S.B., Liao, Y., Chen, Q.H., Huang, D.J., 2016. Investigation and control of beach litter pollution in China. Res. Environ. Sci. 29 (10), 7 (In Chinese).
Zhao, X.Y., Xiong, K.X., Zhou, Q., Tu, C., Li, L.Z., Luo, Y.M., 2020. Composition and sources of plastic debris and microplastics on the tidal flats of Sangou Bay. Yellow Sea. Marine Environmental Science 39 (4), 529–536.
Zhu, C.Y., Li, D.N., Sun, Y.X., et al., 2019. Plastic debris in marine birds from an island located in the South China Sea. Mar. Pollut. Bull. 149, 1–4.