



## Transboundary debris in Indonesian frontier and outermost island: A preliminary case study of Nipah Island

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### Abstract

Anthropogenic debris in marine pollution is one of the significant environmental problems. The objective of the research was focused on the abundance and the distribution of debris found on Nipah Island, Riau Island Province, which was surveyed at ten sampling points, as a preliminary monitoring. Abundance and distribution were estimated with line transect of 50m x 3m. Debris items were categorized by the type of material from the NOAA Marine Debris Program. The abundance and weight calculated each of the types, and simple identification of country supplier also determined from the labels of the plastic. The result showed the average debris abundance of  $7.05 \pm 6.71$  items/m<sup>2</sup> and an average weight of  $1.67 \pm 3.98$  kg/m<sup>2</sup>. The most debris abundance found in every station were plastic (single-use plastic bottle/cup), lumber, metal, and glass. Stranded lumber was the dominant weighted samples, followed by plastic debris. Approximately 51.60% of total plastic (food wrappers) with identifiable labels were from Malaysia (24.26%), Indonesia (23.68%), Singapore (2.33%), and elsewhere (1.33%). In order to manage transboundary debris, science is the primary point to obtain proper alternative handling. In order to make successful marine pollution prevention, it is necessary to have a good education and outreach program, a reliable system of law and policy, and law enforcement to the government and private sector.

**Keywords:** frontier island, outermost island, plastic waste, stranded debris, Nipah Island

### Abstrak

**Sampah lintas batas di pulau perbatasan dan terluar di Indonesia: studi pendahuluan di Pulau Nipah.** Sampah dari kegiatan antropogenik dalam pencemaran laut merupakan salah satu permasalahan lingkungan. Tujuan dari penelitian ini adalah untuk *monitoring* awal, kelimpahan, dan distribusi sampah di Pulau Nipah Propinsi Kepulauan Riau, Indonesia dimana sampling dilakukan pada sepuluh titik pengamatan. Jumlah sampah serta sebaran diambil berdasarkan transek garis 50m x 3m. Sampah digolongkan berdasarkan kategori sampah laut menurut NOAA. Setiap kategori sampah dihitung berdasarkan kelimpahan dan beratnya. Hasil penelitian menunjukkan kelimpahan sampah rata-rata  $7,05 \pm 6,71$  buah/m<sup>2</sup> dan berat rata-rata  $1,67 \pm 3,98$  kg/m<sup>2</sup>. Sampah yang paling banyak ditemukan di tiap lokasi pengamatan adalah plastik (botol/gelas plastik sekali pakai), kayu, logam, dan kaca. Kayu yang terdampar adalah sampel berbobot dominan, diikuti oleh jenis plastik. Sekitar 51,60% dari total plastik dengan label yang dapat diidentifikasi berasal dari Malaysia (24,26%), Indonesia (23,68%), Singapura (2,33%), dan tempat lain (1,33%). Dalam rangka pengelolaan sampah lintas batas, ilmu pengetahuan menjadi poin utama untuk mendapatkan penanganan alternatif yang tepat. untuk menyukseskan pencegahan pencemaran laut.

**Kata kunci:** pulau perbatasan, pulau terluar, sampah plastik, sampah terdampar, Pulau Nipah

## Introduction

In the last decades, marine pollution due to the waste from anthropogenic activities has been recognized as a global environmental problem. Marine debris is defined as any persistent solid material that is manufactured or processed and disposed of or abandoned into the marine environment (Kershaw, 2015). Based on fact, 4.8 - 12.7 million tons of plastic waste predicted to enter the ocean (Jambeck et al., 2015) and 46% of the plastic being generated displays its float ability as originally produced (Karbalaee et al., 2018; Li et al., 2016), and capable of delivering impacts in areas far away from sources (Carson et al., 2013; Duhec et al., 2015; Eriksen et al., 2014; Maximenko et al., 2012). Indonesia suspected as the second-largest contributor to marine plastic pollution all over the world (Jambeck et al., 2015). After being introduced into aquatic environments, plastic will be degraded and losing its structural rigidity due to physical, chemical and biological processes (Iwasaki et al., 2017; Löhr et al., 2017; Schulz et al., 2017) and fragmented into 70% macroplastics (size > 2.5 cm), 11% mesoplastic (5mm - 2.5cm) and 3% microscopic (size of < 5mm) (Bergmann et al., 2015; Cozar et al., (2014); Eriksen et al. (2014), called microplastics and nanoplastics (Andrady, 2011; Barnes et al., 2009; Horton et al., 2017; Thompson et al., 2004).

Marine debris causes a damaging effect on marine biota. Seabirds, fish, sea turtle and marine mammals (Acampora et al., 2016; Boerger et al., 2010; Clukey et al., 2017; Foekema et al., 2013; Teuten et al., 2009) are suffering due to entanglement, get stuck/trapped, and mistaking plastic for food (Gregory, 2009; Thompson et al., 2009; Van Franeker et al., 2011). It was previously only related to the aesthetic (Galgani et al., 2013; Gregory, 2009); in fact, marine debris has a “time bomb” consequence. As generally documented in several publications and obviously can be seen dumped across the coastal area, it will lead to the question about how much is the actual number of total debris (Eriksen et al., 2014; Jambeck et al., 2015; Lebreton & Andrady, 2019; Lebreton et al., 2012; Lebreton et al., 2017), where debris will be driven (Bucci et al., 2020; Nistor et al., 2017; Zhang, 2017), how the circumstance will be in the future (François Galgani, 2015; GESAMP, 2015; Ivar Do Sul & Costa, 2014), and its effect to our lives (Cordova, 2020; Lee, 2015; Newman et al., 2015; Watkins et

al., 2015). Moreover, it will also increase public awareness, develop scientific research, and various effort to reduce marine debris problems (Kershaw, 2015).

Marine debris is a transboundary problem that is embedded in wasteful patterns of development and use, inadequate waste and lack of infrastructure, lack of sufficient legal and policy mechanisms, lack of compliance and a scarcity of financial capital. It has been a concern of the international community and was explicitly discussed in 2012, Earth Summit 2012 in Brazil (Rio+20 International Conference). Marine debris problem, especially plastic, will become a severe concern until 2030. These problems are spotted as a problem through the 14th Sustainable Development Goals point 1 (SDGs) 2015-2030. Furthermore, marine (plastic) debris management has been stated in Global Program of Action for the Protection of the Marine Environment from Land-based Activities 1995, United Nation Convention on the Law of the Sea (UNCLOS), and MARPOL Annex V. In Indonesia, several marine debris managements are regulated in Law of the Republic of Indonesia (e. g. No. 27/2007, No. 32/2014, No.18/2008) and Presidential Decree (No. 97/2017 and No. 83/2018). In order to reach successful management, it needs a comprehensive understanding of both marine pollution and human behavior.

In Indonesia, the evidence has been mentioned in the finding of large and small-sized plastic debris in the freshwater (river and/or lake), coastal area and deep-sea sediment, and in coral reefs ecosystem (Alam et al., 2019; Cordova & Hernawan, 2018; Cordova, 2020; Cordova & Nurhati, 2019; Cordova & Wahyudi, 2016; Purba et al., 2019; Purwiyanto et al., 2020; Syakti et al., 2017, 2018). However, the updated information of marine debris, its distribution, and its impact on the ecosystem are insufficient, particularly in Indonesia's boundaries area. In fact, transboundary debris has a specific problem, because geolocation of Indonesia between the Pacific Ocean and the Indian Ocean and is adjacent to other countries. Disadvantage incurred by this condition is stranded debris originating from elsewhere. Therefore, it is necessary to conduct a preliminary study of transboundary debris in Nipah Island, as the frontier and the outermost island according to the Law of the Republic of Indonesia No. 27 of 2007. Nipah Island has an area of 62 Ha (0.62 km<sup>2</sup>),

strategically located between Malacca Strait and the South China Sea, and one of the global busiest shipping lanes (Hand, 2018). This preliminary research was focused on the abundance and the distribution of debris found on Nipah Island, which is the neighboring country of Singapore and Malaysia. The results of this study can be used as primary data and justification for a marine debris management plan, especially in frontier and outermost islands of Indonesia.

### Methodology

The research was conducted in the frontier and the outermost island of Indonesia, Nipah Island, Riau Islands Province on April 2017. The sampling method was adapted from previous research (Kumar et al., 2016; Lippiatt et al., 2013). Debris sample was collected at ten sampling point representatives around the island (Figure 1). Sampling sites were identified from the cartographic analysis provided by the Marine Corps of The Nipah Island. Moreover, anthropogenic pressures zones according to the cardinal directions were identified since no difference in accumulation rate for samples collected at different intervals (Sheavly, 2010). The substrate covered on the sites was relatively similar, which was sand with tetrapod (concrete structures used to prevent coastal erosion). The number of occurrences, allocation, and distribution was estimated with line transect of 50m x 3m (150 m<sup>2</sup> of total).

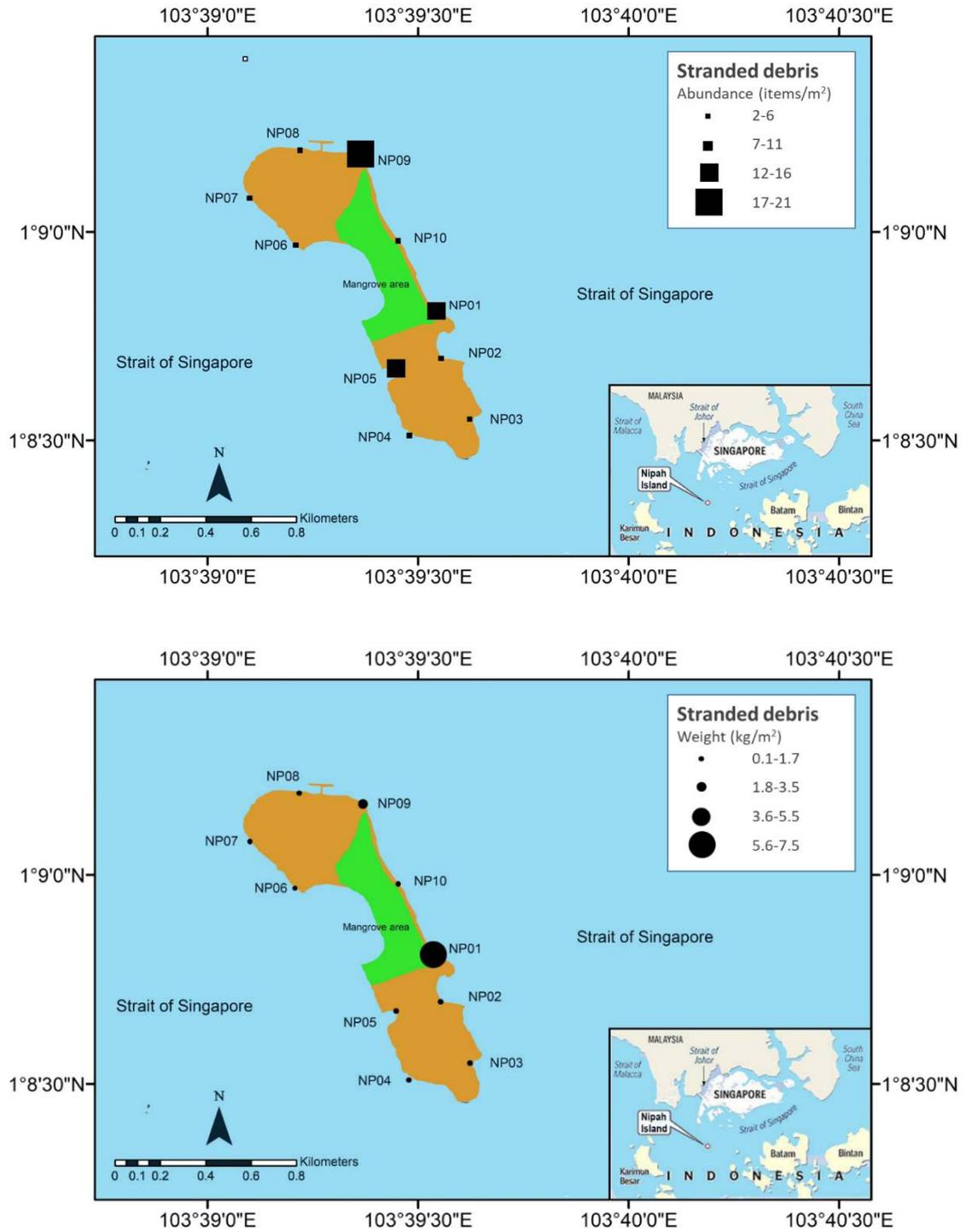
The transect was placed in a supratidal area, where the sites are clearly visible tidal boundaries; thus, sampling points were between the highest high tide area and the lowest low tide area (Li et al., 2018). Most stranded debris studies focus on large, recognizable debris, as they are easily detected, easily retrieved, and can provide additional details intact (e.g. country of production). Debris sample was identified within seven categories: plastic, metal, glass, processed lumber/paper, cloth/fabric, fishing lure/nets, and other/unclassified. These categories were adapted from the types of material listed in the NOAA Marine Debris Program (Lippiatt et al., 2013). Then, the abundance of occurrence was calculated by using Kenko hand tally counter. Each category was weighted by using a digital scale of Weston

Digiscala Clarita (type W7SD-CL5S) with 0.1 g accuracy. In this study, the country of origin was simply investigated to determine the source of marine debris obtained from the stranded debris monitoring. A country label or flag sticker would seem to indicate that a product has been produced in ("made in") a specific country.

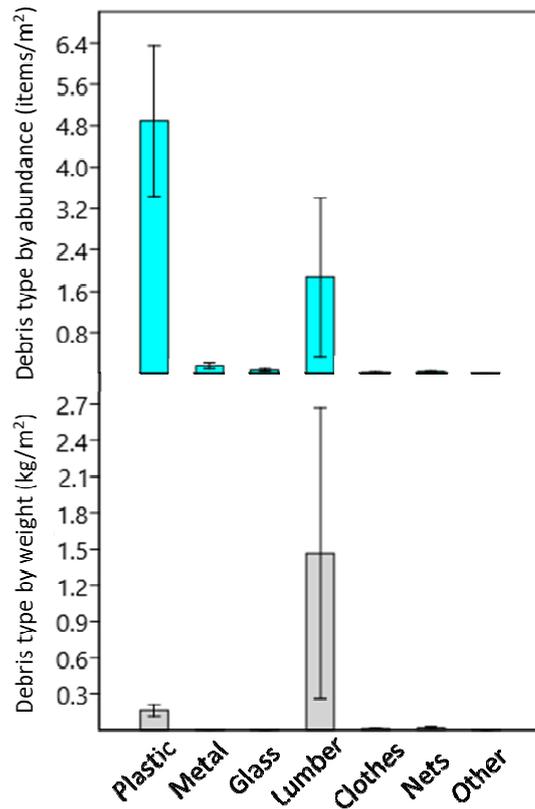
The total amount of stranded debris present in Nipah Island in 2017 was estimated in three steps, (1) the total beach area was measured using aerial imagery in Google Earth Pro (data April 2017), (2) the mean density of the categories surveyed from transects were calculated, (3) to estimate the total abundance and weight of stranded debris in Nipah Island, the total abundance and weight of debris were extrapolated by multiplied the mean density with the total beach area. Statistical test to determine the classification between debris by abundance, debris by weight and between the country of manufacture, were performed with non-parametric statistical test through Kruskal-Wallis and Post hoc Mann Whitney-U-Test using PAST3 (Hammer et al., 2001).

### Results

Plastic and lumber were dominant debris item found in the coastal area of Nipah Island. Based on the results of this study, the average abundance of accumulated debris in the entire sampling point was 7.05±6.71 items/m<sup>2</sup> and the average weight was 1.67±3.98 kg/m<sup>2</sup>. The average number of abundance and weight of marine debris in Nipah Island can be seen in Figure 1 and 2. Based on the debris types (Figure 2), more than half of the total debris (59.23%) or 4.893±4.830 items/m<sup>2</sup> were plastic (especially single-use bottle and cup), 37.30% or 1.871±5.092 items/m<sup>2</sup> were lumber, 1.94% or 0.160±0.214 items/m<sup>2</sup> were metal, and 0.81% or 0.067±0.086 items/m<sup>2</sup> were glass. Based on the debris weight, the dominant with 87.63% or 1.466±3.988 kg/m<sup>2</sup> was lumber, then 9.8% or 0.164±0.162 kg/m<sup>2</sup> were plastic, 1.28% or 0.021±0.030 kg/m<sup>2</sup> were fishing lure/nets, and 0.72% or 0.012±0.018 kg/m<sup>2</sup> were cloths/fabric. There was a statistically significant difference between plastics and lumber ( $p < 0.05$ ) with the other debris type.



Gambar 1. Peta lokasi sampling di Pulau Nipah dengan kelimpahan dan berat dari sampah terdampar.  
 Figure 1. Map of sampling location in Nipah Island with abundance and weight of stranded debris.



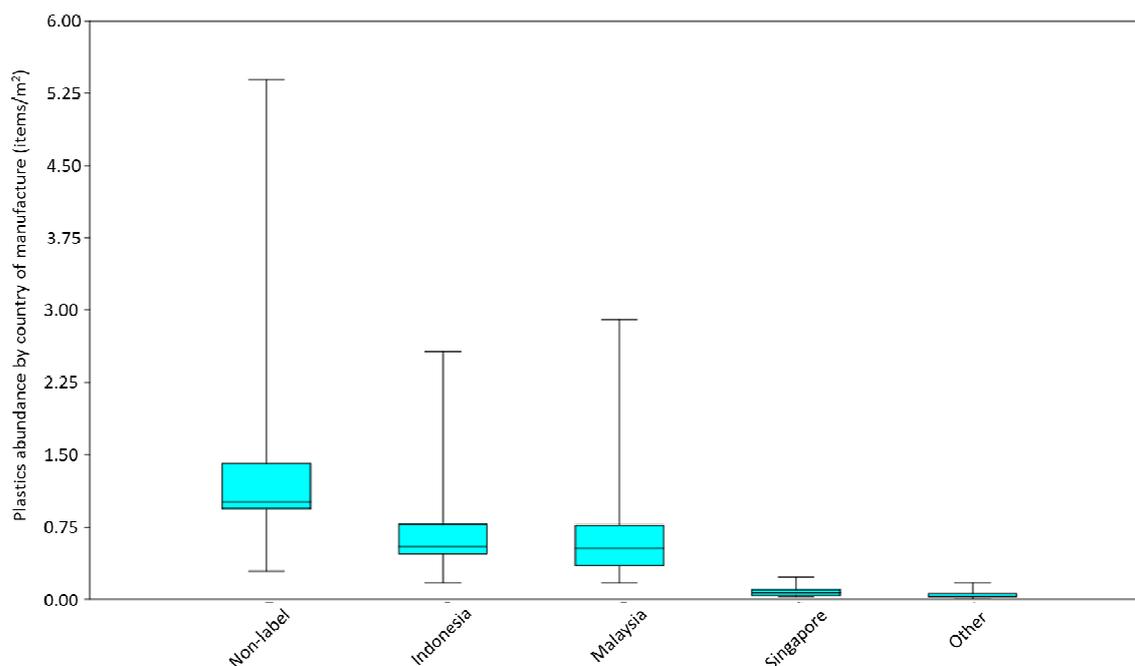
Gambar 2. Rata-rata kelimpahan dan berat dari sampah terdampar di Pulau Nipah.  
 Figure 2. The average number of abundance and weight of stranded debris in Nipah Island.



Gambar 3. Sampah terdampar di Pulau Nipah pada lokasi NP01 (a), NP02 (b), dan NP09 (c).  
 Figure 3. Stranded debris in Nipah Island on sampling area NP01 (a), NP02 (b), and NP09 (c).

Descriptive analysis of the entire site in this research revealed 9 of 10 sites were dominated by plastic debris with an average abundance of 1.07-16.67 items/m<sup>2</sup>, and an average weight of 0.03-0.56 kg/m<sup>2</sup>. Site 1 (NP01, Figure 3a) was the only one which was dominated by lumber with an average weight of 13.44 kg/m<sup>2</sup> and an average abundance of 17.15 items/m<sup>2</sup>. Meanwhile, the presence of lumber in other sites was significantly

low, with an abundance range of 0.05-1.47 items/m<sup>2</sup>, and a weight range of 0.04-1.16 kg/m<sup>2</sup>. Nipah Island has a circumference of 4255.78 m, the total accumulation of debris from all categories was estimated up to 30005 items with a total weight of 30.29 tons. Therefore, plastic debris was likely accumulated up to 3.42 tons, whereas lumber was likely up to 11.67 tons.



Gambar 4. Kelimpahan sampah plastik dari identifikasi label.

Figure 4. Plastics debris abundance from a label identification.

A careful observation (Figure 4) on the origin litter revealed that the dominant samples were product of Malaysia (24.26% or  $0.86 \pm 0.87$  items/m<sup>2</sup>), followed by Indonesia (23.68% or  $0.84 \pm 0.75$  items/m<sup>2</sup>), Singapore (2.33% or  $0.08 \pm 0.06$  items/m<sup>2</sup>), and elsewhere (1.33% or  $0.05 \pm 0.04$  items/m<sup>2</sup>). However, the rest of the samples was unidentifiable (48.41% or  $1.72 \pm 1.67$  items/m<sup>2</sup>) (Figure 4). There was a significant difference between non-label debris “made in” Indonesia and “made in” Malaysia with “made in” Singapore and “made in” other countries ( $p < 0.05$ ).

## Discussion

The potential sources and causes of marine debris on Nipah Island were identified. A preliminary result of debris on the Nipah Island in April 2018 indicated there are an estimated 30005 items (average  $7.05 \pm 6.71$  items/m<sup>2</sup>) of debris weighing 30.29 tons (average  $1.67 \pm 3.98$  kg/m<sup>2</sup>) distributed across this frontier and outermost island. Plastic debris was likely accumulated up to 3.42 tons, whereas lumber was likely up to 11.67 tons. This number was quite surprising because Nipah Island is located in the Malacca Strait area that has a heavy current and continuously leads to

the north. The Strait of Malacca has a length of 805 km, with an average depth of approximately 25 m and a current speed of around 2 m/s (Sakmani et al., 2013). The current flows from the Pacific Ocean and the South China Sea northward toward the deeper and northernmost Indian Ocean (Sakmani et al., 2013). Haditiar et al. (2020) stated the strong current in the central and southern parts of Malacca, with the residual current of Malacca Strait moving towards Singaporean Waters in the south. With that oceans current condition, it should be able to reduce the potency of stranded debris onto Nipah Island. Where the current is quite hard and always leads to the north, the potential for stranded debris to stuckin Nipah Island is relatively small. However, in fact, quite a lot of stranded debris were found on Nipah Island. The data from this study may be underestimate the actual volume of debris present on Nipah Island as all potential waste sources were not sampled. For instance, items buried under the surface and debris inside the tetrapod were excluded. Consequently, our data on Nipah Island stranded debris densities are conservative and values should be interpreted as minimum assessments.



Gambar 5. Sampah plastik terdampar di Pulau Nipah berdasarkan identifikasi label.  
Figure 5. Stranded plastics debris from Nipah Island based on label identification.

The present study showed that the stranded debris in Nipah Island was equivalent or more extensive than in other areas, such as 4.72-55.67 items/m<sup>2</sup> in Cocos Islands Australia (Lavers et al., 2019), 0.10-7.50 items/m<sup>2</sup> in Pulau Seribu, Indonesia (Willoughby, 1986), 16.8–41.6 items/m<sup>2</sup> in Cilacap coast, Indonesia (Syakti et al., 2017), 3-347 items/m<sup>2</sup> in tourism beaches around the South China Sea (Zhao et al., 2015), 29–393 items/m<sup>2</sup> in beach around the Portuguese Coastlines (Martins & Sobral, 2011).

Based on the result of label identification analysis, the plastic debris was likely from the anthropogenic litter of land-based of Sumatra, Malaysia, and Singapore that was driven by the current. The debris sources were impossible to predict, only an assumption that the items have been produced in a specific country. In the case of an unidentified label in single-used bottle/cup (48.41%), it was likely caused by long weather exposure to the plastic including chemical reaction, physically processed by heat/temperature (thermal degradation), sunlight exposure (photodegradation), and also biological aspect or biodegradation (Muthukumar & Veerappapillai, 2015). Plastic debris stranded in Nipah Island that was manufactured from other countries may have been driven by the current and also caused by shipping activities in this area. Besides, it was also likely came from the activities in the waters of Malacca Strait itself. In 2017, 84,456 ships were passing through the Malacca Strait, by carrying

more than 25% of loads across the world's ocean (Hand, 2018). Sealine activity in this area will increase the potential case of waste discharges from ship.

Therefore, in relation to transboundary debris, the presence of plastic debris in Nipah Island must be treated carefully. According to Sheavly and Register (2007), litter from land-based activities was the most significant contributor to marine pollution. Bergmann et al., (2015) and Sheavly and Register (2007) also showed that most of the marine debris source was from land-based, whereas the rest of it was from ocean-based including fisheries and shipping. Considering the characteristic of plastic (solid, easy to use, low price and portable), it has been used to replace other material such as lumber, metal, concrete, and rock (Riani & Muharram, 2016). Therefore, plastic is increasingly applied in daily living (Riani & Cordova, 2018). Average production of plastic is 78 million tons per year, 40% of the product will end up in landfill, 32% will distribute to the environment including the marine environment, and only 14% of the total is collectable for the recycling (Ellen MacArthur Foundation, 2016).

Regarding this situation, Indonesia has the potential to receive transboundary debris that was derived from the Pacific Ocean, and later became a transboundary debris source for the Indian Ocean. These results underline the increased need for successful policy implementation and

mitigation, which at present concentrate mainly on locally cleaning up visible waste. Clean-ups based exclusively on the surface debris of a single frontier and the outermost island will take months to negotiate. This will require a considerable training period, and costs enormous expense. Therefore, this severe threat due to this transboundary debris urgently needs to be resolved by all stakeholder involved because it will have an impact on the environment and eventually escalate to the economic aspect. The Indonesian government should also implement the National Plan of Action according to Presidential Decree No.83/2018 for Combating Marine Debris. A multi-prong approach is necessary and urgently needed in order to prevent plastic products from entering the ocean (Wu et al., 2016). As mentioned above, science is a significant key to obtain proper handling management as well as the 3R program (Reduce, Reuse, and Recycle). Education and outreach program, reliable system of law and policy, and also law enforcement to government and private sector, including substantial investment in strategies to restrict plastic production, use and waste management, are the elements to support marine pollution prevention.

### Conclusion

This preliminary study in Nipah showed that the waste on this transboundary and outermost island is estimated at 30005 items (average of  $7,05 \pm 6,71$  items/m<sup>2</sup>), with weight of 30.29 tons (average of  $1,67 \pm 3,98$  kg / m<sup>2</sup>), plastic and lumber are the dominant debris. The current may have driven plastic debris stranded in Nipah Island. The most observed of labelled print in single-used bottle/cup was the product from Malaysia, Indonesia, and Singapore, even though most of them were no longer identified.

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### Author Contribution

M.R. Cordova, T. Purbonegoro, R. Puspitasari designed the study, devised the project, the main conceptual ideas, and proof outline. M.R. Cordova, T. Purbonegoro, R. Puspitasari wrote, review and revise the article with input from other authors. R. Subandi, M.T. Kaisupy, S.P.A. Wibowo, Nurjain, Suparmo, and S. Sapulete contribute in data curation and formal analysis.

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