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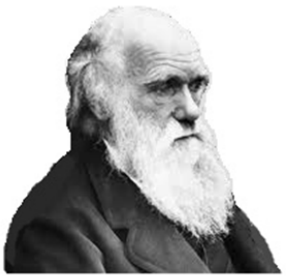

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Distribution of Macro Debris in Savu Sea Marine National Park (Kupang, Rote, and Ndana Beaches), East Nusa Tenggara, Indonesia

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ABSTRACT

Marine debris has emerged as a global issue that poses risk to environment systems. This study aimed to investigate the distribution of marine debris in Savu Sea Marine National Park, particularly in Kupang City, Rote Island, and Ndana Island (which are transboundary islands in the Australian and the Indian Ocean). Six beaches were assessed on this study, which comprised of total 12 transects. Debris collected from sampling sites weighed 52.14 kg, with abundance 4.447 ± 1.131 kg/m2 and 215.417 ± 35.609 item/m^2. Most debris pieces were accumulated on high tide line and the area that many residents passed through. In terms of type, food wrapper and plastic bag dominated the debris composition due to their occurrence in every transect. It is strongly suggested that beached debris in Kupang and Rote was sourced from the population activities, whereas in Ndana was transported from other places via ocean currents.

***Keywords*:** beached debris, Savu Sea, tourism, distribution, abundance, Savu Sea Marine National Park

1. INTRODUCTION

Marine debris has become a global issue due to its impact on the ecosystem [1], human [2], economy [3-4], marine life [5-8], aesthetic value [9-10], and transboundary issue. Marine

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debris also was raised as a major issue at United Nations Conference in Rio de Janeiro about sustainable development in 2012 (Rio+20). It was clearly stated at this conference that marine debris would affect the balance of marine biodiversity.

Most common types of debris that found in the world's oceans are plastic, glass, and metal [11]. Plastic is the most common type, due to its durability in nature and difficult to degrade naturally. A study estimated millions of tons of plastic dumped into the ocean annually [2]. Furthermore, Ocean Conservancy declared the top 10 of beached debris types: cigarette, plastic bottle cap, beverage bottle, plastic bag, food wrapper, plastic glass, glass, straw, beverage can, and paper bag [12]. In Pangandaran Beach, Indonesia, beached debris is sourced from tourists, traditional fishermen, and transported from other areas [13].

This issue has been a challenge for Indonesia to overcome, in regard to Indonesia's status as the world's second-largest contributor to plastic marine pollution [14]. Indonesia as an archipelagic country with complex ocean circulation, which could alter alternately due to local factors. Those oceanic characteristic show a strong correlation to marine debris, which is called "transboundary issue". Moreover, research on marine debris in Indonesia are relatively scarce, only 22 publications from 1986 to 2018 (based on literature tracking from google scholar, research gate, and Scopus). Those research are considered partial, limited to certain periods, and incapable to represent the entire of Indonesia waters. Several marine debris publications in Indonesia, namely Uneputty and Evans in the Ambon Bay [15] and Seribu Islands [16], Evans *et al*. in Ambon [17], Syakti *et al.* in Cilacap, Central Java [18], and Purba, Syamsuddin, Sandro, Pangestu and Prasetio in Biawak Island [19]. Research on marine debris is predicted to be able to answer many interest, namely the ocean's health, ocean sovereignty, and transboundary issue.

On this study, most of the surveyed sites are tourism beaches located in Savu Sea Marine National Park. Marine debris study in this particular area is indispensable. Firstly, this area represents Indonesian waters with coral reef biodiversity, high biota, and constitutes as migration paths of cetaceans and other commercially potential fish. Secondly, the Savu Sea acts as one of the outflows of Indonesia Through flow that moves towards the Indian and Atlantic Oceans. Lastly, there are core and utilization zone so the condition of this area can be understood from various sources. Therefore, this area is suitable to assess, whether to create a database of marine debris or to establish the new policy in overcoming this issue in particular.

2. MATERIALS AND METHODS

2. 1. Study Area

Table 1. Sites Characteristics

No	Sites	Location	Remarks
1	Oesina	Kupang	Tourism
2	Oenggae	Rote Ndao Regency	Residential area
3	Oeseli	Rote Ndao Regency	Tourism, aquaculture
4	Ndana	Ndana Island	Southernmost island of Indonesia, Uninhabited island,

No	Sites	Location	Remarks
5	Nembrala	Rote Ndao Regency	Tourism, residential area
6	Tiang Bendera	Rote Ndao Regency	Tourism

Savu Sea Marine National Park is located at the heart of Coral Triangle Indonesia. This is the largest Marine Protected Area (MPA) in Southeast Asia, with around 3.35 million acre area covering 10 regencies in East Nusa Tenggara. On this study, we surveyed 6 beaches situated in Kupang City, Rote Island, and Ndana Island (Table 1, Figure 1). Most of those beaches are utilized for tourism and local fisheries, except Ndana Island, which is an uninhabited island and located at the south of Indonesia.

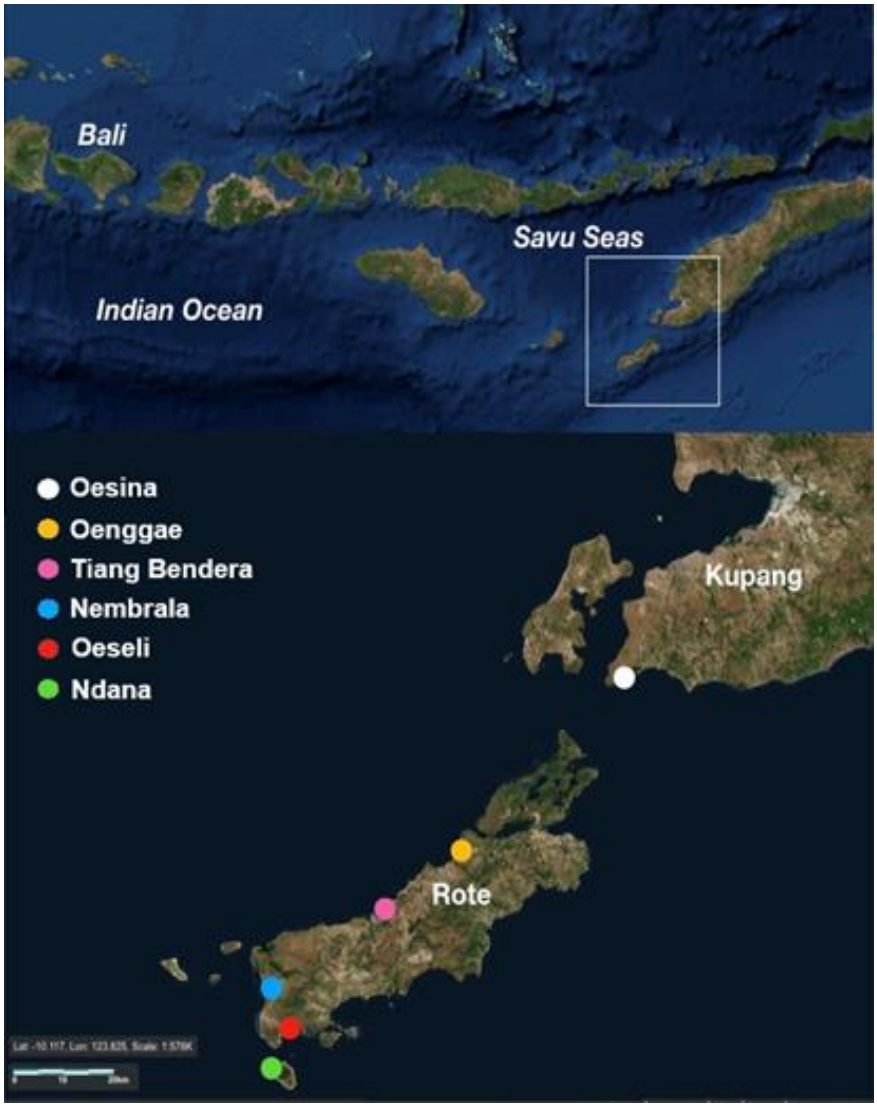

Figure 1. Study Area

2. 2. Data Collection

Debris collecting was conducted on 4 – 7th June 2018, using Ocean Conservancy (OC) form as a reference for debris categories (accessed from http://www.oceanconservancy.org). The form itself contains types, categories, weight, sampling locations, and transect length to fill out. Using Line Transect between 100 meters on each side [20], all debris > 2 cm (macro debris) were collected, categorized, counted, and weighed. We also used GPS to mark all the beached debris. Equipment that was used during the survey were sacks, scales, roll meters, and GPS. The items were sorted into categories according to OC form (a. most likely to find items, b. fishing gear, c. packaging material, d. personal hygiene, e. other trash, f. Tiny trash less than 2.5 cm). There was an additional category, g. clothes and footwear, due to its absence on the original form. However, those type of debris were frequently found on sampling sites.

We involved 5-10 person to collect the debris and took 2-3 hours. Technically, surveyors were divided into several groups consist of three to five persons. Interviews with the locals were also carried out in order to gain more information. Debris abundance was also calculated from each station. To calculate debris abundance, the weight and items number of the debris were divided by the sampling area per square meter.

3. RESULT AND DISCUSSION

3. 1. Debris Distribution

According to the survey results, we found that Savu Sea Marine National Park was polluted by various types of marine litter. The pieces of beached debris were collected from 6 beaches and 12 transects, each transect was 100 m long. The number of transects varied with each beach depended on visually estimated debris distribution and the entire coastline length. Total debris pieces collected weighed 52.14 kg, consisted of total 2585 items.

The heaviest debris was collected from Oesina, weighing 15 kg from one transect only. Meanwhile, Ndana was the least polluted beach regarding the weight, only weighing 3.12 kg from two transects (Table 2). The debris weight in Oesina was the heaviest due to the survey on that beach was conducted during high tide phase, when the debris was newly transported. Oesina also was strongly affected by tourism, since it was included as a popular tourist destination. From the survey result, Tiang Bendera and Oeseli can also be classified as the debris-trapping beach, with 11.30 and 10.95 kg debris respectively. These beaches were also popular beaches among tourists, even Oeseli was also affected by aquaculture activity. Meanwhile, in Oenggae, which is bordered by a residential area, the debris weight reached 7.95 kg, higher than the famous Nembrala beach which reached 3.82 kg.

The different results showed in terms of total debris items. Beach with the most total items found was Tiang Bendera (799 items), while the least number of total items was collected in Oenggae (255 items) (Table 2). Some debris was not found in intact form, therefore it caused the debris weight was not always in line with items number. In popular tourist destinations, such as Oesina, Nembrala, and Tiang Bendera, most the debris pieces were found in the intact form. Otherwise, it differed from Ndana where most the pieces found was tiny fragments, spread throughout the coast. Of all the surveyed sites, Ndana was the site with the least influences in terms of debris-generating. It is located far from a residential area and most unlikely to be affected by tourism and aquaculture activities. As for the correlation coefficient

between weight and total items were 0.48, which showed a moderately strong correlation between the variables [21].

Table 2. The result of Marine Debris Survey in 6 Beaches.

No	Sampling Site	Number of Transects	Weight (kgs)	Total Item	Weight (kgs) per m^2	Item per m^2
1	Oesina	1	15.0	323	0.150	3.23
2	Oenggae	2	3.70	201	0.037	2.01
			4.25	54	0.043	0.54
3	Oeseli	2	5.75	281	0.058	2.81
			5.20	129	0.052	1.29
4	Ndana	2	2.00	268	0.020	2.68
			1.12	206	0.012	2.06
5	Nembrala	3	1.37	100	0.014	1.00
			2.21	169	0.022	1.69
			0.24	55	0.002	0.55
6	Tiang Bendera	2	6.80	345	0.068	3.45
			4.50	454	0.045	4.54

Average debris abundance were 4.447 ± 1.131 kg/m^2 and 215.417 ± 35.609 item/m^2 from total transect line 1.2 km. Based on the sampling sites location, the beach with the highest abundance (item/m^2) was Tiang Bendera, with 7.99 item/m^2 (Figure 2). However, this number is lower than the debris abundance in Northeast Coast Brazil (910 items/m^2) [22], although higher than the debris abundance in Southern beaches of Australia (3.16 item/m^2) [23]. Meanwhile, the beach with the highest abundance (kg/m^2) on this study was Oesina (0.15 kg/m^2).

It could be predicted that the beached debris in most of these beaches was sourced from various sources. Beached debris in Oesina and Oeseli are mostly influenced by aquaculture (seaweed) and local fishermen, due to the frequent occurrence of rope and buoy pieces (plastic bottles were often used as buoys in aquaculture activities) debris along the beach. On the other hand, debris accumulation in Oenggae is allegedly affected by local residents, since most part of this beach bordered by residential area. Tiang Bendera and Nembrala, which are the popular

beaches for local and international tourists in Rote, were allegedly affected strongly by tourists in terms of debris accumulation.

In conclusion, most of the beached debris in Kupang and Rote beaches are strongly suggested come from local residents through various activities. Nevertheless, beached debris in Ndana was allegedly sourced from other places that transported via ocean currents, regarding Ndana's status as the outer island in Indonesia that is uninhabited.

To conclude the generating factors, it is assumed that residents, tourism and aquaculture generate debris that eventually transported and beached, although further studies are necessary to assess the local current, seasonal characteristics, and social aspects as well. To investigate the debris distribution in each site, we conducted GPS marking on every beached debris found.

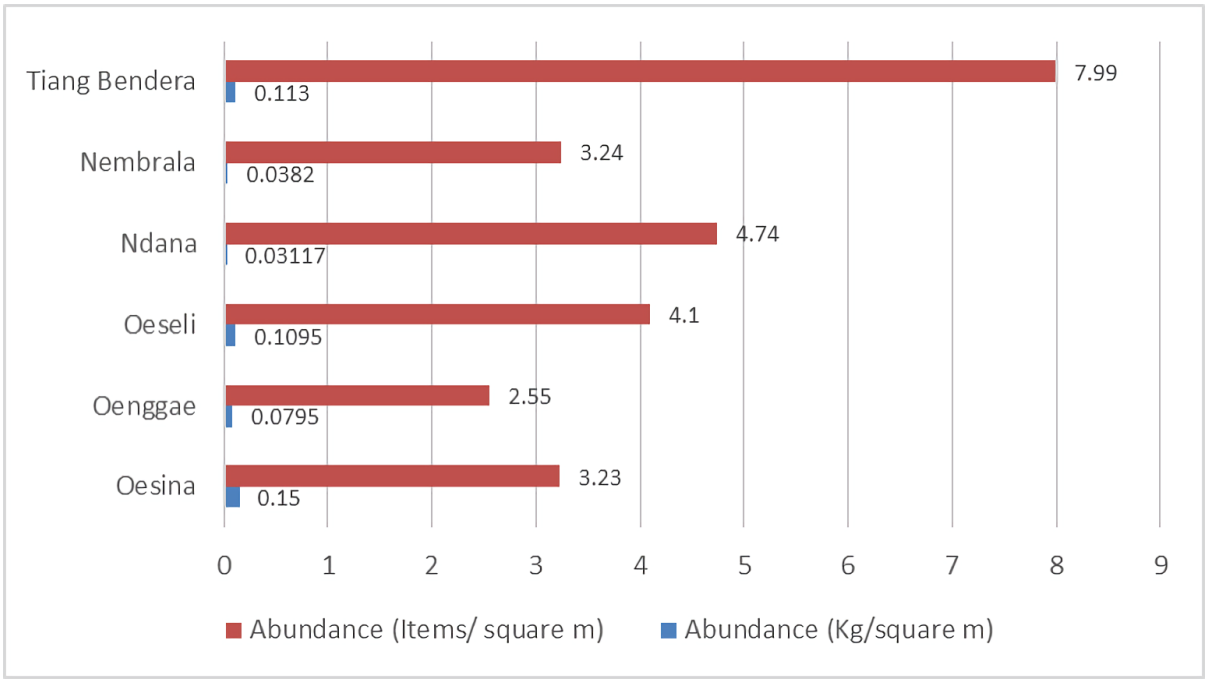

Figure 2. Debris Abundance Based on Number of Items and Weight (kgs) per area (m^2)

Debris distribution in each site showed similar characteristics where most the pieces were beached at the high tide line [24]. During high tide, debris from the ocean would be easily transported to the coast. Other than that, debris pieces were found dry and mostly found in the resident pathways. Visually, beached debris covered approximately 1/5 beach area with 40 – 50% density (Figure 3).

In popular tourist beaches, like Nembrala, Oisina, and Tiang Bendera, most the debris pieces were concentrated at the entrance area. In Oenggae, debris was concentrated in the residential area.

In Oeseli and Ndana, most of the debris was accumulated at high tide area. During the survey, garbage bin was not available on those beaches, contrast to the purpose of the beaches as tourist destinations.

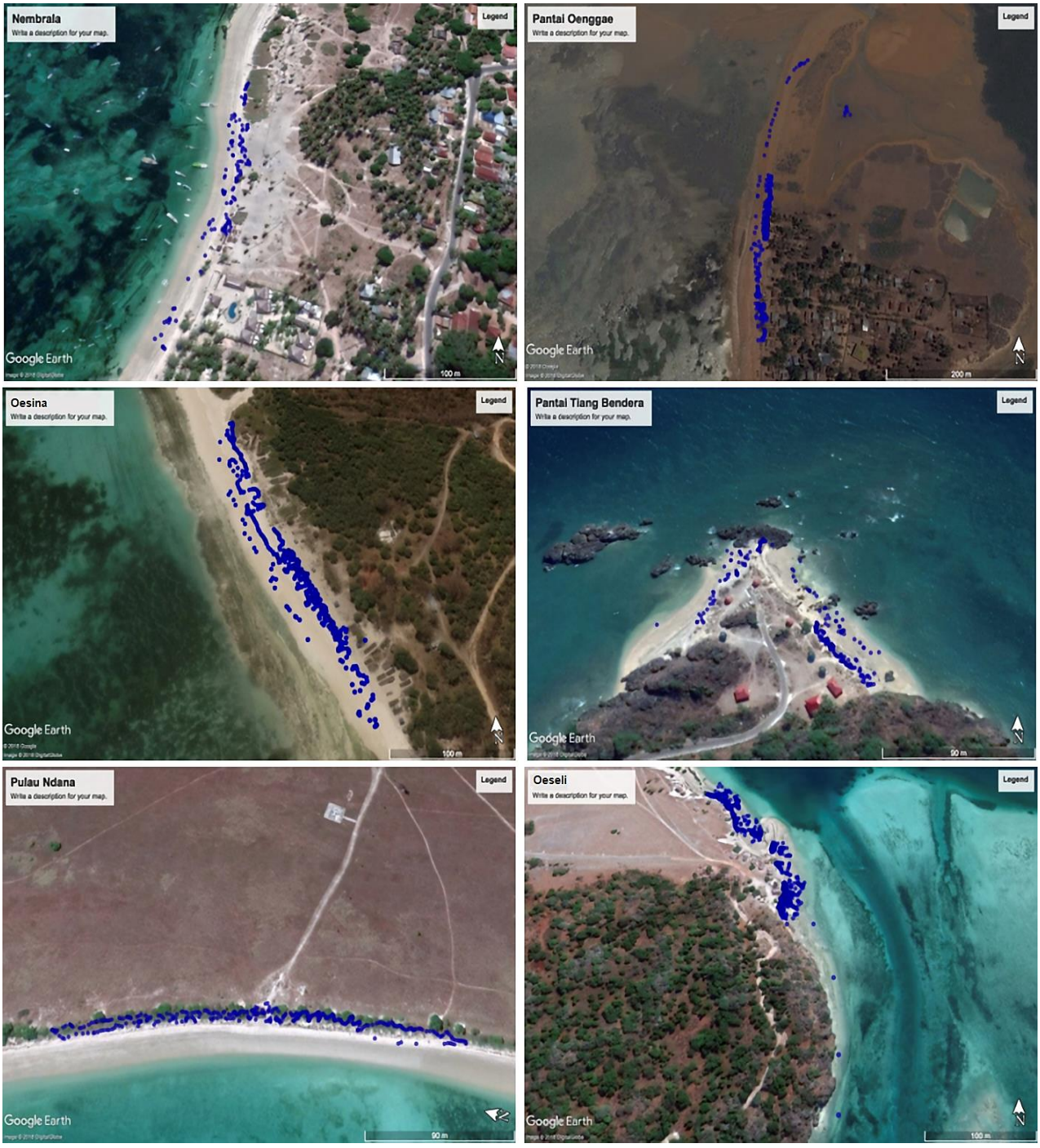

Figure 3. Debris Distribution

3. 2. Debris Type

Generally, beached debris found in this study constituted synthetic materials. There are 7 debris categories, symbolized by the alphabet A – G, each category consists of several different

types of debris that are adjusted to its categories. The highest debris proportion in this study was category A (most likely to find items), B (fishing gear), and F (tiny trash less than 2.5 cm).

Table 3. Percentage of Each Debris Category

No	Sampling Site	Category (%)						
		A	**B**	**C**	**D**	**E**	**F**	**G**
1	Oesina	78.94	7.43	4.95	1.24	2.17	3.41	1.86
2	Oenggae	66.67	6.47	13.93	0	9.45	0.50	2.98
		59.26	5.56	12.96	0	5.56	9.26	7.41
3	Oeseli	44.13	24.56	7.83	0	12.01	6.41	4.98
		67.44	17.05	0	0	8.53	0	6.98
4	Ndana	53.36	19.40	2.24	0	5.22	18.28	1.49
		48.54	15.53	5.34	0	6.31	20.87	3.40
5	Nembrala	60.00	18.00	9.00	0	4.00	9.00	0
		57.40	7.69	28.40	1.18	2.96	1.18	1.18
		56.36	21.82	7.27	0	3.64	10.91	0
6	Tiang Bendera	62.32	1.16	10.43	0	4.93	16.81	4.35
		59.03	1.10	7.93	0.22	3.96	23.57	4.18
Average		59.45	12.15	9.20	0.22	5.73	10.02	3.23

Remarks: A) most likely to find items; B) fishing gear; C) packaging materials; D) personal hygiene; E) other trash; F) tiny trash less than 2.5 cm; G) clothes and footwear

According to Table 3, the most dominant category was A, followed by B, F, C, E, G, and lastly D. Category A consisted 18 debris types, which 17 of them were found in sampling sites, comprised of 48.54 – 78.94%. All of the types from category B and F were found in every site, though in less quantity, with 1.10 – 24.56% and 0 – 23.57% for B and F respectively. Category C consists of 5 debris types, only 3 of them were found, comprised of 0 – 28.4%. Category E consists of 7 debris types, 6 of them were found, comprised of 2.17 – 12.01%. The least percentage was D with 0 – 1.24%, consists of 4 debris types which only 1 of them was found.

Debris type collected varied, depended on condition and activities around the sites. Marine debris might be sourced from land-based waste, poor waste management, riverine input, beach littering behavior, and marine activities like aquaculture, shipment, and fishing activities [25 – 26]. Anthropogenic debris was also found in several sites, like food and detergent wrapper, and diaper, highly indicates that most debris was sourced from local residents.

Anthropogenic debris has changed significantly for the last 30 – 40 years since synthetic materials were introduced [27].

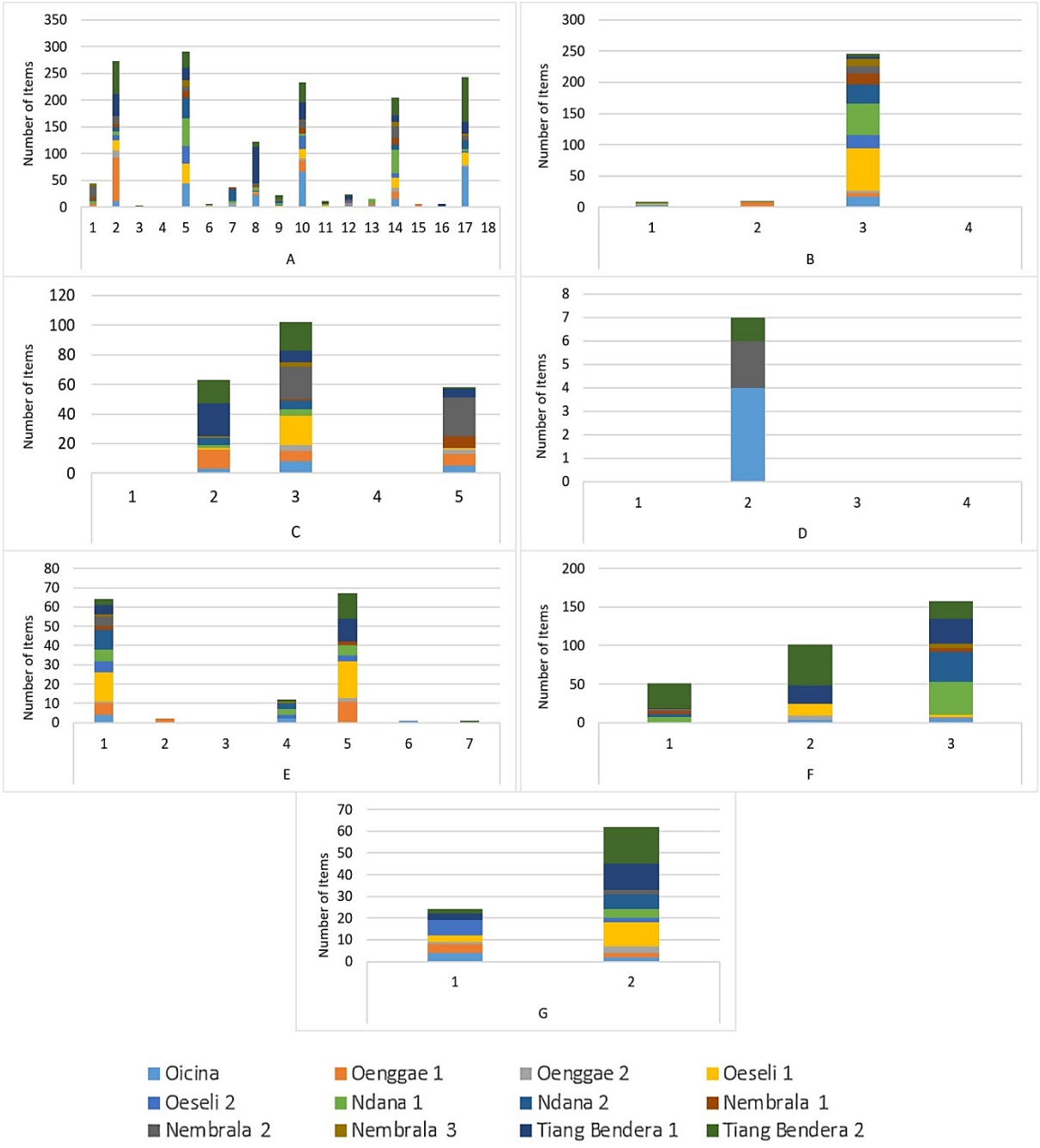

Figure 4. Debris Composition at Every Site Transects, Category A-G Based on OC Form

Debris found at beaches indicated the activities that could generate them in the first place. The result of this study suggested that local residents and fishermen were top debris

contributors, due to the abundance of A and B debris category (Figure 4). According to the graph, category A and B made up the highest debris proportion at the survey transects reaching around 300 pieces, whereas category D made up the least proportion with occurrences at three transects only.

Generally, debris in category A are made of synthetic materials and found dominantly on most beaches. The most common type found were A2 (food wrapper), A5 (plastic bottle caps), A8 (straw), A10 (beverage bottle), and A17 (plastic cup) that found over 50 pieces in certain sites. A2 and A14 were found in every transects. Most of these were made of plastic, which possesses a high persistence in the environment and low density that makes it easy to transport in the long distance before eventually accumulated on beaches [2].

B category consists of B1 (fishing trap and buoy), B2 (fishing nets), B3 (rope), B4 (fishing line). This debris could be associated with the fishing activities. B category is quite common in Indonesia's beaches. The most common B categories that found in sampling sites was B3, which found in Oeseli with 90 pieces.

C category consists of C1 (six-pack holders), C2 (other plastic/foam packaging), C3 (other plastic bottles, e. g. bleach, oil), C4 (strapping bands), and C5 (tobacco wrap). C5 type was found in higher quantity than any other C types, with 34 pieces in Nembrala. Therefore, C3 were more evenly distributed in every site, with a maximum of 27 pieces in Tiang Bendera. C3 type was presumably sourced from residents and ship maintenance activities.

D category consists of D1 (condom), D2 (diaper), D3 (syringe), and D4 (tampon applicator). D2 was the only type found in sites, such as Oesina, Nembrala, and Tiang Bendera. This debris type was found in higher quantity in Oesina, with 4 pieces. D category is strongly associated with one's personal hygiene. It is strongly suggested that if this type were found in beach, it is most likely that this waste is dumped there on purpose.

E category consists of E1 (appliances), E2 (balloon), E3 (cigar tips), E4 (cigarette lighters), E5 (construction materials), E6 (fireworks), and E7 (tires). Type E composition varied in every site. E3 and E6 were not found in sites. E1 and E5 were found in Oeseli, with 21 pieces and 22 pieces respectively.

F category consists of F1 (foam pieces), F2 (glass pieces), and F3 (plastic pieces). F1 was the least quantity compared to the other two types, with maximum pieces found 32 pieces, though this type spread in almost every site, except in Oeseli and Oenggae. F2 was not found in Nembrala and Ndana, although found mostly in Tiang Bendera with 72 pieces. F3 was found in every site, mostly found in Ndana with 82 pieces. Plastic pieces that found in Ndana was mostly in a fragile state. It is highly indicated that those fragments generated from degraded plastic that has been traveled a long distance before eventually beached in Ndana.

G category was a frequent type of debris in sites, though initially, this category is not available on the OC form. G1 (clothes) was mostly found in Oeseli with 10 pieces. Clothes debris could be possibly originated from natural disasters and cruise accident. G2 (footwear) was found in every site, mostly found in Tiang Bendera with 27 pieces.

According to the survey, the most dominant type of debris found was plastic in several different forms, such as food wrapper, beverage bottle, bottle cap, cup, and plastic bags. Plastic dominance as marine debris also occurred in other countries, like Falkland Islands [28], Brazil [22], Belgium [29], Chile [30], and Ghana [31]. Other than category A, category B also dominant in several places, similar with debris type in Biawak islands [19] where most of the beached debris consisted of ropes and net pieces.

In conclusion, debris composition was dominated by synthetic materials, like plastic, nylon, fiber, and rubber. The accumulation of those materials might risk the beach aesthetic values. The most dominant debris type was food wrapper (A2), and other plastic bags (A14). Due to all the different conditions in every sites, those two types were frequently encountered during the survey.

4. CONCLUSIONS

Beached debris collected from Kupang, Rote and Ndana weighed 52.14 kg with average abundances 4.447 ± 1.131 kg/m2 and 215.417 ± 35.609 item/m2. It is strongly predicted that this debris was sourced from local residents through various activities. However, it is strongly suggested that beached debris in Ndana was transported from other places via ocean currents. Category A (most likely to find items) debris was the highest debris proportion, comprised of 48.54 – 78.94%. Beached debris covered approximately 1/5 beach area, mostly accumulated in high tide and residential area, most of them were found dry along the coast. The most dominant debris types were food wrapper and other plastic bags, which were found in every transects.

Despite its status as the largest Marine Protected Area in Southeast Asia, Savu Sea Marine National Park is susceptible to debris pollution, regarding its activities and oceanic complexities. Therefore, the establishment of interdisciplinary approaches is reasonably necessary to create strategies in overcoming this particular matter, as well organizing the educational campaigns to local residents and fishermen in order to reduce the marine waste.

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