Overview of Existing Waste Processing Techniques in Small Islands of Pulo Aceh, Seribu, Karimunjawa and Wakatobi

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Abstract. Indonesia is an archipelagic country with more than 17,000 islands scattered across the country. Unique ecosystems, such as mangrove and coral reefs that have a very important ecological function, can be found in coastal area along with highly diverse species. Coastal area is also place for many major cities, while small islands became tourist destination. Human activities in these areas have generated pressure to the coastal resources and environment sustainability, (e.g.: the emerging unmanaged waste in major cities and tourist destination, which leaked to the ocean, then drifted, dispersed, and stranded in other shores). This study aims to identify various waste management practices in selected sites of small islands (e.g.: Pulo Aceh, Seribu, Karimunjawa, Wakatobi), where they have limited resources to managed waste. The result indicated that waste management practices in each place are vary, adjusted with their specific condition (e.g.: total population, daily waste generation, and availability of waste processing technology). Local community have adopted number of techniques to manage domestic waste, as well as stranded marine debris in their island. Based on the field observation, the key success factors of waste management in small islands will depend on the involvement of local community, good collaboration among stakeholders, also output of waste processing practice should bring direct and indirect benefit for the society, low-cost, and eco-friendly.

Keywords: marine debris, small island, waste processing

1. Introduction

Indonesia is a vast archipelagic country comprises of 17,495 islands with 99,903 km of coastline, and 77 % of its sovereign territory is ocean [1][2][3]. Important ecosystems with a high biodiversity such as mangroves, coral reef, seagrass, seaweed, and other marine resources can be found in Indonesian coastal
area. On the other hand, many high populated cities also developed in this area, which cause conflict between natural resources use and preservation [4]. Common issue experienced by coastal city is the insufficient waste management capacity (particularly plastic waste) by local governments, thus caused a lot of unmanaged waste entering major rivers then leaked into the ocean and become marine plastic litter [5][6]. Based on the study by Jambeck et al., [7], Indonesia was referred as the second contributor of marine plastic litter to the ocean. Once the litter leaked into the sea, these debris will be drifted to other regions [8], shredded into pieces (micro/nano plastic), and/or stranded in some coast/shore or in small islands [9]. This marine plastic debris has caused serious environmental problems, as well as threatening human health on small islands, since they have limited resources and open area for managing stranded marine debris and domestic waste. Further study indicated that poor waste collection and processing are the main sources of leakage to the ocean [10].

As for the legal basis for controlling marine pollution, national regulations have been issued by Government of Indonesia (GoI) [11][12][13][14][15], which refer to UNCLOS 1982, MARPOL Convention and Sustainable Development Goals (SDGs) 14. Based on the Presidential Regulation No. 97/2017 on the National Strategy and Policy for Solid Waste Management, GoI has set a target to reduce the municipal solid waste by 70% in 2025. Yet, current achievements remain far below target, and most of actions were concentrated on main islands while small islands were left out.

Therefore, this study aims to provide the general overview of existing waste management practices in small islands in Indonesia run by local government or by community, whether local communities in small islands have adopted traditional practices of waste handling (e.g.: burned, buried, piled in open area, or discarded at sea) which has negative effect to the environment; or they have adopted better and more eco-friendly practices. This study is conducted in four small islands (Pulo Aceh, Seribu, Karimunjawa, and Wakatobi), which are known as tourist destination, rich of natural resources, and high diversity of coral reef. This study is important since advantages and disadvantages of each practice are also discussed, which can be learned by stakeholders in other small islands in Indonesia, to improve their capacity in managing waste which adapted to each characteristic of island, available resources and facilities, also capabilities of local communities.

2. Materials and methods

2.1. Brief description of study sites
This study is conducted on selected small islands of Karimunjawa, Aceh, Seribu Islands (in 2020), as well as in Wakatobi, from November 2018 to January 2019 (Figure 1). These islands are selected due to different type of waste source and possible threat, as briefly described below:

2.1.1. Pulo Aceh Island. This inhabited Islands is part of Aceh Besar region of Aceh Province, which located in the northwest end of Indonesia, adjacent to the one of the most crowded shipping lines in the world, namely the Malacca strait. Most of inhabitants in this Islands are work in agriculture sector. This Island also known for the attractiveness of its beaches, but unfortunately, these pristine beaches are littered by plastic debris stranded from elsewhere, carried out by ocean currents. Unfortunately, there is no open area that officially used by local government as dumpsite/landfill.
2.1.2. Seribu Islands. This Islands consist of 105 small islands located in the north of Jakarta city, the capital of Indonesia. Wastes in this Islands are generated from domestic (households and tourism activities) as well as marine litter stranded from other places, since the location of this Island is close to high populated cities such as Jakarta, Serang, Bekasi (in Java Island), and Lampung (in Sumatera Island). These major cities are traversed by dozens of rivers which possibly drifting litter into the Java Sea. At a certain time, the volume of waste is high, until they cover mangrove roots (Figure 2). Wastes in these small islands are managed by Provincial Government of Jakarta, operated by Sub-Department of the Environment Service of Seribu Islands. Since the absence of dumpsite in this Island, most of wastes are transported to the terminal dumpsite/landfill (Tempat Pembuangan Akhir or TPA) of Bantargebang in Java Island.

2.1.3. Karimunjawa Islands. This island is located in Java Sea, part of Jepara Region in Central Java Province, where 5 out of 27 small lands are inhabited. This Islands is known as a top marine tourism site in the province, indicated from the number of tourists that increased over time (before the pandemic), and currently being developed as a Strategic National Tourism Area. Yet, the increasing tourist visit is not followed with the improvement of waste management in this area and aggravated by stranded marine debris from elsewhere [16], particularly from major cities in the north coast of Java Island (Figure 2).

2.1.4. Wakatobi Islands. Wakatobi is an acronym from Wangi-Wangi, Kaledupa, Tomia and Binongko; four small islands located in the Southeast Sulawesi Province. This island is considered as the centre of world’s coral triangle, where its diving sites are very famous worldwide. Due to its importance, this island is declared as National Marine Park since 1996 by the Government of Indonesia. Waste found in this area are generated from household and from stranded marine debris from elsewhere (Figure 2) and threatened the effort of coral and endangered marine species conservation in this area.
2.2. Method and materials
This study is expected to identify the small islands community’s practices in managing domestic, as well stranded marine debris in their island; whether local community implement the traditional and unsustainable practice of waste management (such as burning, buried, or discarded in the sea) or practicing a better and more sustainable approach. Data of this study is acquired from field observation, deep interview and focus group discussion with relevant stakeholder on-site, also from desk study. Except for field observation in Wakatobi Islands, we conducted a two-day period of waste sampling in residential area of Kulati village and Huuntete beach, during September and November of 2018, also in January 2019. The purpose of this sampling is to compare the volume between domestic waste and stranded debris which collected in two different monsoon and transition season. Several sampling materials such as garbage bags, ropes, stakes, roll meters, smartphones, and scales are utilized to classified managed and unmanaged waste in the area.

3. Results and discussion
Small islands possess limited capacity to process waste that generated not only from domestic (household and tourism activity), but also from marine debris that stranded in their shore, carried by ocean current from unknown source. Based on information from local communities in Pulo Aceh Island namely Sahabat Laut (SaLut) who conducted study on waste issues in Pulo Aceh Island in 2016, the dominant waste is plastic bottle (50.7%), then followed by other form of plastic waste (41.5%) and non-plastic waste (7.7%). Similar condition also occurred in Seribu Islands, where this Island is adjacent to Jakarta Bay and Sunda Strait, and surrounded by densely populated cities such as Jakarta, Tangerang, Serang, Bekasi (in Java Island) as well as Lampung (in Sumatra Island). These cities are traversed by dozens of big rivers that flow into the Java Sea, which indicated as the potential origins of stranded debris in Seribu Islands. Stranded marine debris also found along eastern shore of Karimunjawa during our field study, covering its white sandy beach. Seasonal marine debris have threatened to coastal environment of Karimunjawa which has abundant resources such as mangrove, beach forest, seagrass, seaweed, and coral reefs [17][18][19][20].

A more detailed study on seasonal marine debris was conducted in Wakatobi Islands by Yayasan Konservasi Alam Nusantara (YKAN), by comparing type and weight of plastic debris with waste generated from household in Kulati village. The sampling was conducted in three different periods that represent each monsoon season: east monsoon from September to October 2018, transition period in November 2018, and west monsoon in January 2019. The result (Figure 3) indicates that the amount of household waste relative constant for all monsoon season, different with marine debris that changed significantly, depend on the season.
Figure 3. Comparison between household waste and stranded debris in Kulati Village, Wakatobi. (left) Comparison between total amount of seasonal stranded debris and household waste. (right) Comparison between total amount household waste and stranded debris collected during the observation period, resulting stranded debris (51%) is slightly higher than household waste (49%). (YKAN, 2019).

Stranded marine debris found along the shore in small islands area have generated negative impacts to the environment. In Karimunjawa and Wakatobi which known as tourist destination, seasonal stranded debris has caused unpleasant sights and bad odour which triggering complaints from visitors [21]. Pile of wastes that cover mangrove’s pilot root, could inhibit mangrove growth and natural regeneration process (Figure 2). Since the impact of waste to coastal environment in small islands is serious, any practical, low-cost, and eco-friendly solution is urgently needed. Also, it is noteworthy that a good coordination between local governments in small island with their neighbouring regions become essential, since the possibility of inter-aquatic waste exchange is high [22]. It is expected that through a good communication between inter-stakeholder and inter-sector, waste management can be optimized based on the function of each coastal zone that has been set and must be specific needs of each region.

Since 2017, the Government of Indonesia under the supervision of the Coordinating Ministry of Maritime Affairs and Investment have been running five strategies to eliminate marine debris issue at national scale, i.e.: (1) initiate national movement to raise awareness of stakeholders; (2) improving land-based waste management; (3) eradicating marine debris in coastal and ocean; (4) financing mechanism, strengthening institution, monitoring and law enforcement; and (5) research and development.

While at local scale (particularly in small islands), we found that there are various of domestic waste management that have been practiced, not only activities that are conducted regularly, but also activities that organized occasionally (by local government, local communities and Non-Government Organization (NGO)), in order to mitigate/reduce plastic waste issue, as summarized in Table 1 below (based on field observation and compiled information in [23]).
Table 1. Waste management practices in four small islands in Indonesia resulted from field observation, deep interview and focus group discussion with relevant stakeholder on-site.

| No | Existing Practices                                                                 | Study sites       |
|----|-------------------------------------------------------------------------------------|-------------------|
|    | **Existing waste management practices (regular basis):**                             | Pulo Aceh Island  |
|    | 1. Eliminating organic waste using L-Box incinerator                                | ✓                 |
|    | 2. Compost heap and urban farming                                                   | ✓ ✓ ✓             |
|    | 3. Eco brick                                                                         | ✓ ✓               |
|    | 4. Hazardous and toxic substances (B3), as well as e-waste                           | ✓                 |
|    | 5. Transport waste residues to the terminal landfill (TPA) on the nearest mainland  | ✓ ✓               |
|    | 6. Waste bank                                                                       | ✓ ✓ ✓             |
|    | 7. Waste bioconversion using maggot                                                 | ✓                 |
|    | 8. Backfilling for land reclamation                                                 | ✓                 |
|    | 9. Recycled for handicraft or pots                                                  | ✓ ✓ ✓             |
|    | 10. Sorted inorganic wastes are shredded using waste shredder machine               | ✓                 |
|    | 11. Develop waste dumpsite/landfill in the area                                      | ✓ ✓ ✓             |
|    | 12. Directly burned                                                                 | ✓ ✓               |
|    | 13. Waste to energy using pyrolysis machine                                         | ✓                 |
|    | **Other initiatives for mitigating/reducing marine debris (occasional):**            |                   |
|    | 14. Beach clean-up action                                                            | ✓ ✓               |
|    | 15. Educating local inhabitants on the importance of a good waste management       | ✓ ✓               |
|    | 16. Local government's regulation on banning the single use of mineral water cup/bottle | ✓ ✓               |
|    | 17. Provisioning equipment for plastic and organic waste processing                 | ✓ ✓               |
|    | 18. Develop building and equipment for waste processing machine                     | ✓                 |
|    | 19. Provisioning waste transporter equipment                                         | ✓ ✓               |

**Yayasan Konservasi Alam Nusantara (YKAN)**, an NGO whom provide community assistance in Wakatobi Islands, have suggested recommendations for waste management in small islands, i.e.: (1) develop a systematic and efficient waste collection, transfer and disposal system, including good sorting process, started from the origin (houses); (2) reduce, reuse, recycle of inorganic waste; (3) composting the organic waste; (4) raising awareness of waste management, by teaching to elementary school students and conduct training in making compost from organic waste; (5) strengthening capacity for women, by training in making handicrafts or souvenirs; (6) capacity building for community groups and village governments to form a self-sufficient group or body that able to run an integrated waste management.

Despite various efforts in managing waste on small islands have been practiced, we also investigated further on the advantages and disadvantages of each regular practices to the socio-economy and environment, through a series of focus group discussions (by inviting local stakeholders), to obtain their experiences in carrying out those various waste processing practices. The result (as summarized in Table
2 below) can be used as a reference for local government and communities in other small islands in Indonesia who have been impacted by similar problems.

**Table 2.** Advantages and disadvantages of each waste management practices in four small islands resulted from field observation, deep interview and focus group discussion with relevant stakeholder on-site.

| No | Waste processing practices | Advantages | Disadvantages |
|----|-----------------------------|------------|---------------|
| 1. | Eliminating organic waste using L-Box incinerator (in Seribu Islands) | • Efficiently clean the environment  
• Produced residues can be utilized as liquid fertilizer for plants  
• Reducing waste volume that sent to the terminal landfills (TPA) of Bantar Gebang, hence reducing the operational cost | • Organic and inorganic waste should be separated first, where organic waste can be decomposed  
• L-Box facility should be far from residential area, as the incineration smoke could polluting the surrounding air  
• Disturbing odor from incineration process  
• This incinerator is considered as an expensive investment for local government/community. |
| 2. | Compost heap for urban farming (in Pulo Aceh, Seribu and Wakatobi Islands) | • Composting will produce an organic fertilizer to substitute the use of pesticide for urban farming, which improve the quality of plant. Vegetables and plants become more fertile, free from pesticide usage  
• Reducing waste volume that transported to the terminal landfills (TPA)  
• Composting process is quite simple and environmentally friendly. Materials are collected from local neighborhood.  
• Empowering local inhabitants and increase their income | • Compost contains less nutrients than chemical fertilizers  
• Require more organic waste input to produce a desired amount of compost residues  
• Require more efforts and time to sorting the waste  
• Require a training of composting process for local inhabitants in early phase and monitoring its sustainability during implementation phase |
| 3. | Eco brick (in Seribu and Wakatobi Islands) | • Another solution to reduce waste volume in shore area, low cost and easily done  
• Triggering waste sorting activity, to separate organic and inorganic waste  
• Reducing waste volume that sent to the terminal landfills (TPA) | • Eco brick is a flammable material, since it made from plastic  
• Not all plastic waste can be used for eco brick, materials must be selected first  
• Require more time and efforts to sorting the waste  
• Require a training of Eco brick making process for local inhabitants in early phase and monitoring its sustainability during implementation phase |
| 4. | Hazardous and toxic substances (B3), as well as e-waste (in Seribu Islands) | • Hazardous substances are still processed using L-Box  
• B3 wastes only generated from local hospital in Seribu Islands | • The B3 wastes should be processed using specific Standard Operating Procedure (SOP) |
| No | Waste processing practices | Advantages | Disadvantages |
|----|-----------------------------|-------------|---------------|
| 5. | Transporting waste residues to the terminal landfill (TPA) in the nearest mainland (in Seribu Islands) | • Waste residues from L-Box process (in Kelapa and Harapan Island) are transported by Provincial Government of Jakarta using Samtama vessels on a regular schedule  
• Reduce waste volume in the island | • Wastes in other islands are left over, hence require additional cost if these wastes should be transported.  
• Require a high operational cost to transport waste from small islands to the terminal landfill (TPA) of Bantar Gebang |
| 6. | Waste bank (in all study sites) | • Waste recycling process can reduce waste volume, empowering local inhabitants and improving their income | • These waste banks are not operated daily; depend on the personnel and cash flow availability  
• Require more time and efforts to sorting the waste |
| 7. | Waste bioconversion using maggot (in Seribu Islands) | • Can be easily done by waste management operator. Does not need chemical substances and excessive equipment  
• Provide additional income for inhabitants  
• Recycling process can reduce waste volume and source for fish feed | • Price of maggot seed is expensive  
• Require more time and efforts to sorting the waste and nurturing black flies |
| 8. | Backfilling for land reclamation (in Seribu and Karimunjawa Islands) | • Plastic wastes which used as backfilling materials, are easy to find without additional cost.  
• Backfilling is considered as a low-cost practice to reduce waste volume for land reclamation, which will increase the area of the island as the number of local inhabitants are increasing over time. | • Plastic as material for backfilling could threatening the coastal ecosystem and degrading the environment quality  
• Require time and effort to sorting waste that suitable for this purpose  
• Not suitable for tourism area |
| 9. | Recycled for handicraft or pots (in Pulo Aceh Island and Wakatobi Islands) | • Reduce waste volume sent to the terminal landfills and provide additional income for inhabitants | • Require more time and efforts to sorting the waste |
| 10. | Other inorganic wastes are shredded using waste shredder machine (in Pulo Aceh Island and Wakatobi Islands) | • Empowering local communities and improving incomes  
• Reduce waste volume sent to the terminal landfills | • Require a high investment for machinery, equipment, and trainings |
| 11. | Develop the terminal dumpsite/landfill (TPA) in the area (in Karimunjawa and Wakatobi Islands) | • Waste can be transported and dumped in a single location  
• Can reduce waste volume in temporary dumpsite (TPS)  
• Can be used as input for waste-to-energy plant | • Require a large area which will need to be enlarged in the future, whereas the availability of unused land on small islands is very limited.  
• Require a high investment (initial cost)  
• Location should be far from residential areas, because of bad odor originated from TPA |
| 12. | Directly burned (in Karimunjawa and Wakatobi Islands) | • Could eliminate domestic waste directly  
• Reducing waste volume | • The smoke and bad odor could pollute surrounding air |
Table 1 and 2 above show that each site has applied different approach for processing their waste, based on each local need and capacity, also the expected result of waste processing (eliminated/incinerated, or recycled into handicraft, fertilizer, gas, etc). Each of these waste processing techniques have advantages and disadvantages to the society, economy, and environment. Therefore, we should encourage local communities to stop any waste processing practice if only it causes negative impact to their environment in order to maintain the sustainable use of natural resources. Afterward, agreed waste processing technique should be proposed to the local government as an important part of the Integrated Coastal Zone Management (ICZM) plan involving spatial planning element and ecosystem-based approach. Hence, applied waste management method can be aligned with ICZM plan that has been applied on site [24][25][26][27]. As an example, there is a lesson learned from waste processing in Seribu Islands using L Box incinerator that placed in the same area with the houses. There are two incinerators that being suspended after several children were reported having respiratory disorder due to the smoke generated from incinerators. In the context of ICZM framework, incinerator can be revitalized if the local stakeholders (government and communities) have agreed the new site that suitable for these incinerators, far from houses, preventing the smoke and residues polluting community and environment (air, soil, and water).

Another example of waste processing technique which might cause a negative impact to environment is the utilization of plastic waste as backfilling material for reclamation. Reclamation is needed by densely populated small island such as in Seribu Islands, due to the population growth (Figure 4). Despite the benefits of this practice in reducing the reclamation costs, this technique is probably unsuitable to be used near the tourism site, since it will generate unpleasant sights and odour. Also, there are potential negative impacts to the quality of soil and water, as well as to the health of coastal ecosystem such as mangrove and seagrass (which often located near the reclamation area). Regarding the case of mangrove health, plastic waste that used as backfilling material could cover mangrove’s pencil roots and seedlings, which will disrupt natural regeneration of mangrove forest. In the long term, macro plastics will degraded into microplastics, which easily polluting the ocean, can be consumed by marine biota like fishes and turtles [28][29][30][31][32], and threatening human health eventually. For these reasons, intensive discussions are needed to select and implement the appropriate waste processing techniques as well as zonation planning for the best use of coastal management.

Figure 4. Reclamation using plastic waste as backfilling material in Seribu Islands, Jakarta (Photo by: R Rahmania, 2020).
4. Conclusion

The threat of marine litter to the environment of small islands is considered serious. Hence, any practical, low-cost, and eco-friendly solution is urgently needed. In several small islands, various waste processing techniques have been applied, yet their capacity remain low and require support of facilities, infrastructure, and trainings from local government and private sectors. The key success factors of waste management in small islands will depend on the awareness and active involvement of local communities, also good collaboration among stakeholders; and for these reasons, waste processing practice should bring direct and indirect benefit for local communities. Another important consideration is that waste processing techniques should not harm the coastal environment, which will disrupt the sustainability of coastal resources such as mangroves, seagrasses, coral reefs, as well as sandy beaches along the coast. In the future, waste management activity should be incorporated in the integrated coastal management plan that developed by local government, and should not excluded from other environment monitoring program, to maintain the sustainable use of our coastal resources.

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References

[1] Pusdatin-KKP 2018 Buku Pintar Kelautan dan Perikanan (Jakarta: Pusdatin-KKP)
[2] Nikijuluw V P 2016 Coastal Resources Conservation in Indonesia: Issues, Policies, and Future Directions Geography International Seminar
[3] BPS 2017 Extent and Number of Islands of Each Province in Indonesia, 2002-2016
[4] Sukristijono S 2002 Integrated Coastal Zone Management (ICZM) in Indonesia: A View from a Mangrove Ecologist Southeast Asian Stud. 40 2 200–18
[5] UNEP 2016 Marine plastic debris and microplastics – Global lessons and research to inspire action and guide policy change (Nairobi: UNEP)
[6] Shamshiry E, Nadi B, Bin Mohktar M, Komoo I, Saadiah Hashim H and Yahaya N 2011 Integrated models for solid waste management in tourism regions: Langkawi Island, Malaysia J. Environ. Public Health 2011 1–5
[7] Jambeck J R, Geyer R, Wilcox C, Siegler T R, Perryman M, Andrady A, Narayan R and Law K L 2015 Plastic waste inputs from land into the ocean Science 347 6223 768–71
[8] Rahmania R, Setiawan A, Tussadiah A, Kusumaningrum P D, Yulius, Prihantono J, Gautama B G, Pranowo W S, Aisyah, Nugraha A W, Gusmawati N F, Widjanarko E and Arifin T 2021 Mapping seasonal marine debris patterns and potential hotspots in Banten Bay, Indonesia MARSAVE 2020 IOP Conf. Ser. Earth Environ. Sci. 763 1 1-10
[9] Dobler D, Martinez E, Rahmania R, Gautama B G, Maes C and Farhan A R 2021 Floating marine debris along Indonesian coasts: An atlas of strandings based on Lagrangian modelling. “Monitoring and modelling the circulation of marine debris in Indonesia” project funded by AFD (Jakarta: IRD)
[10] Shuker I G and Cadman C A 2018 Indonesia - Marine debris hotspot rapid assessment: synthesis report (Washington DC: The World Bank)
[11] Anon 1999 Government Regulation No. 19/1999 on Marine Pollution Control (Indonesia)
[12] Anon 2008 Law No 18/2008 on Solid Waste Management (Indonesia)
[13] Anon 2010 Ministry of Home Affairs Regulation No 33/2010 on Household Waste Management (Indonesia)
[14] Anon 2017 Presidential Regulation No. 97/2017 National Strategy and Policy for Solid Waste Management (Indonesia)

[15] Anon 2018 Presidential Regulation No. 83/2018 on the Handling of Marine Plastic Debris (Indonesia)

[16] Argo T A and Rachmawati Y 2021 The Prospect of Implementing Circular Economy of Solid Waste in Small Islands: A Case Study of Karimunjawa Islands District, Central Java-Indonesia IOP Conf. Ser. Earth Environ. Sci. 799 1 1-9

[17] Hafsiardewi R, Sulistiono, Fahrudin A, Surisno D and Koeshendrajana S 2018 Resource management in the Karimunjawa Islands, Central Java of Indonesia, through DPSIR approach AES Bioflux 10 1 7–22

[18] Wijayanto D, Bambang A N, Nugroho R A and Kurohman F 2020 Financial analysis of seaweed cultivation in Karimunjawa Islands, Indonesia AES Bioflux 12 1–10

[19] Winata A, Yuliana E, Hewindati Y T and Djatmiko W A 2020 Assessment of Mangrove Carrying Capacity for Ecotourism in Kemujan Island, Karimunjawa National Park, Indonesia AES Bioflux 12 83–97

[20] Campbell S J, Kartawijaya T, Yulianto I, Prasetya R and Clifton J 2013 Co-management approaches and incentives improve management effectiveness in the Karimunjawa National Park, Indonesia Mar. Policy 41 72–9

[21] Fajrin E R 2019 Identifikasi Komposisi dan Berat Sampah Laut di Ekosistem Pesisir Pulau Karimunjawa dan Menjangan Kecil pada Musim Peralihan 1 di Wilayah Kepulauan Karimunjawa (Brawijawa University Malang)

[22] Schlüter A, Van Assche K, Hornidge A K and Vádianu N 2020 Land-sea interactions and coastal development: An evolutionary governance perspective Mar. Policy 112

[23] Amalia A H 2020 Upaya Pengelolaan Sampah Pulau Karimunjawa Sebagai Destinasi Wisata di Taman Nasional Karimunjawa Jepara (Gajah Mada University)

[24] Elliff C I and Kikuchi R K P 2015 The ecosystem service approach and its application as a tool for integrated coastal management Nat. e Conserv. 13 105–11

[25] Ramesh D A and Vel A S 2011 Methodology of Integrated Coastal Zone Management Plan Preparation – Case Study of Andaman Islands, India J. Environ. Prot. (Irvine,. Calif). 02 750–60

[26] Jones P J S, Qiu W and De Santo E M 2013 Governing marine protected areas: Social-ecological resilience through institutional diversity Mar. Policy 41 5–13

[27] Post J C and Lundin C G 1996 Guidelines For Integrated Coastal Zone Management Environ. Sustain. Dev. Stud. and Monographs Ser. 9 1–16

[28] Wilcox C, Puckridge M, Schuyler Q A, Townsend K and Hardesty B D 2018 A quantitative analysis linking sea turtle mortality and plastic debris ingestion Sci. Rep. 8 1–11

[29] Lestari P and Trihadiningrum Y 2019 The impact of improper solid waste management to plastic pollution in Indonesian coast and marine environment Mar. Pollut. Bull. 149 110505

[30] Gall S C and Thompson R C 2015 The impact of debris on marine life Mar. Pollut. Bull. 92 170–9

[31] Wilcox C, Mallos N J, Leonard G H, Rodriguez A and Hardesty B D 2016 Using expert elicitation to estimate the impacts of plastic pollution on marine wildlife Mar. Policy 65 107–14

[32] Schuyler Q A, Wilcox C, Townsend K A, Wedemeyer-Strombel K R, Balazs G, van Sebille E and Hardesty B D 2016 Risk analysis reveals global hotspots for marine debris ingestion by sea turtles Glob. Chang. Biol. 22 567–76