Assessing cryptic marine fauna diversity as underwater macrophotography (UMP) objects in Sempu Strait, Indonesia

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Abstract. Cryptic marine fauna refers to organisms that live inside habitats that hidden from direct exposure to their outer environment. Its cryptic nature made these animals rarely observed, and hence understudied. Whereas, they are very popular among experienced divers alike as underwater macrophotography objects. The aim of this study is to assess the diversity of cryptic marine fauna on the proximity of coral reef area at Sempu Strait to bring up its underwater macrophotography tourism potential. While the definition of cryptic marine fauna itself could include any major group of marine organisms, we limit the extent of our study only into the four most popular animal groups in underwater macrophotography which are: fishes, sea slugs, arthropods, and flatworms. We conducted underwater surveys using roving diver technique spanning from October 2017 to June 2019 at eleven dive sites of Sempu Strait and yielded 84 species that consists of 45 species of sea slug, 29 Species of fish, 8 species of arthropods, and 2 species of flatworms. The overall fauna diversity shows that Sempu Strait has high diversity of sea slug and cryptic fishes, while the site-specific diversity shows that Stumbut dive site has the highest marine cryptic fauna diversity.

1 Introduction

The terms cryptic marine fauna refers to marine organisms or organism assemblages that live inside habitats that hidden from direct exposure to their outer environment [1]. While on coral reef ecosystem, this definition could be simplified as animal groups that live inside the crevices or burrows, either on a living or dead coral [2]. A study suggest that exposed benthic community is more affected by the ocean's disturbance such as currents and wave [3], while these hidden and well-protected habitats are sheltered by the environmental controls that exist on the reef surface [1]. Cryptic marine faunas are considered one of the most ecologically important groups, as they are playing key role at the ecosystem's trophic level as suspension feeders, predators, herbivores, and detritivors [4]. Some of them even play an important role in controlling the flow of energy within the ecosystem [5-6]. Other

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study suggest that some marine invertebrates are used to assess the impact of over-harvesting, either for food source or ornamental purpose [7].

Despite their ecological importance, the assessment of cryptic species diversity on coral reef ecosystem is often goes undetected, as sampling could be time-consuming [8] or hidden from view and difficult to locate without doing damage to the substrate [9] and in fact that some of cryptic marine fauna species are either undescribed or very hard to be identified [4]. While the terms cryptic marine fauna could include any major groups of marine organisms, including vertebrates, algae, fungi, bacteria, and metazoan invertebrate [1], we are limiting the extent of our study only into the four most popular animal groups in underwater macrophotography, which are cryptic fishes, heterobranch sea slugs, arthropods (crustacean) and polyclad flatworms. Other comprehensive study also include some notable groups like amphipods and other molluscs [10], but we exclude those groups in this study because there is no recorded data about these cryptic species group both from this study or underwater photographer's personal collection around this strait.

The spectacular coloration, small size, and non-aggressive trait made some of these marine cryptic fauna groups are highly photogenic, and therefore being an eye-candy for macro photographers alike [11]. A study also suggests that experienced divers are more attracted to cryptic fishes and invertebrates, while novice diver tends to be more attracted to marine megafauna [12]. Lately, underwater macro photography become a rising ecotourism activity around this strait, as underwater macro enthusiasts around East Java Region and even from other countries are starting to do their hunting activities around this strait. Unfortunately, despite being established as Nature Reserve Area (id: Cagar Alam) since colonial period through *Besluit van den Gouverneur Generaal van Nederlandsch Indie* No: 69 and No.46 dated March 15th 1928 about *Aanwijzing van het natourmonument Poelau Sempoe*, the overall biodiversity of this Nature Reserve and the area around its proximity, both above and below the waters is still much unknown. There are some studies conducted around this area to assess the general status of reef fishes [13-14] and invertebrates [7] [15] but the information provided is still insufficent for underwater macro photography activity because it is only cover the most common fishes and invertebrates species. Therefore, to improve the knowledge about uncommon recorded, and possibly rare species that attract underwater macrophotographers alike, we conducted this comprehensive study to assess the diversity of cryptic marine fauna on the proximity of coral reef area at Sempu Strait to provide better information and to bring up its underwater macrophotography tourism potential.

2 Methods and Materials

A total of 35 dives conducted during the period from October 2017 to June 2019 at eleven dive sites to gather the information around cryptic marine fauna occurrence at Sempu Strait Waters. The dives were conducted involving 2 – 4 experienced SCUBA divers around the coral reefs and their adjacent area. The surveys conducted using the Roving Diver Technique [16], covering areas from 0-25 meters depth, as the Roving Diver Technique did not require to deploy any fixed transect, so the observers are free to search for marine cryptic fauna as they wish. The length of the dive is also varied greatly, as it is only limited by safe diving considerations that usually determined by depth. The technique is chosen considering the cryptic nature, uncertain occurrence, and the highly scattered distribution of marine cryptic fauna. A study done by Schmitt et al. [17] at Southern Hispaniola shows that by using Roving Diver Technique, they found more species of fish compared to the usual 20m transect method. The data source collected during the surveys comes from the detailed photograph of each specimen found during the survey using the Olympus Tough TG-5 and Canon G7X Mark II camera that capable to shot detailed macro photograph images to reveal the detailed morphology that can be useful for identification of each specimen found during the survey.

Table 1. Details on each dive sites (Fig. 1). Abbreviation of each dive site are used in Fig. 2-4 and Tab. 2-5

Dive Site	Abbrev.	General Benthic Cover
Watu Meja	WM	Rock and rubble, low coral cover
Pondok Urang	PU	Sand, rubble, patchy corals
Waru – Waru	WW	Sand, seagrass beds, and massive corals
Kolam Dermaga	KD	Concrete, rocks, and patchy corals
Calo Ilang	CI	Silt and rock, very low coral cover
Teluk Semut	TS	Rocky coral reef, rubble, silt on deeper water
Tanjung	TJ	Moderate hard coral cover, silt on deeper water
Rumah Apung	RA	Silt, artificial reefs
Kondang Buntung	KB	Rock drop-off, moderate corals
Tiga Warna	TW	Moderate hard coral cover, artificial reefs
Stumbut	ST	Silt, soft coral, sponges, and low hard coral cover

The cryptic marine faunas found during the survey are classified into four different groups, which are fishes, sea slugs, arthropods, polyclad flatworms. The identification process is carried out by comparing the morphological details of each specimen from the photograph with material source like books and journals, and also got its taxon verified by the World Register of Marine Species' website [18]. The fishes identifications are mainly compared to identification books [19-21], while the sea slugs are compared to various sources like book [22], scientific publications [23-27], and additionally the Bill Rudman's Sea Slug Forum [28]. The polyclad flatworms identified by comparing to journals [29-32], while the arthropods (crustacean) identifed by comparing to book [33].

Marine cryptic fauna's diversity data is counted using the Shannon – Wiener Diversity Index, a mathematical index that is widely used in ecology and ecological monitoring. This index is chosen during this study because it is not greatly affected by sample size [3]. Compared to another diversity index like Brillouin Diversity Index that require situations where collection is made, sampling was non-random, and the overall community's composition is known [35], Shannon Wiener index could become handy during the survey due to the occurrence nature of cryptic fauna is uncertain and might not be found in a great number. The Shannon-Wiener Diversity Index equation retrieved from Spellerberg, (2008) [34] as follows:

$$H = -\sum_{i-1}^{s} p_i \ln p_i \quad (1)$$

Where H = Shannon's diversity index, s = total number of species in the community, p_i = proportion of S made up of the ith species. This diversity index is counted to compare the total cryptic marine fauna group diversity, study site's total diversity, and cryptic marine fauna group within the study site's diversity.

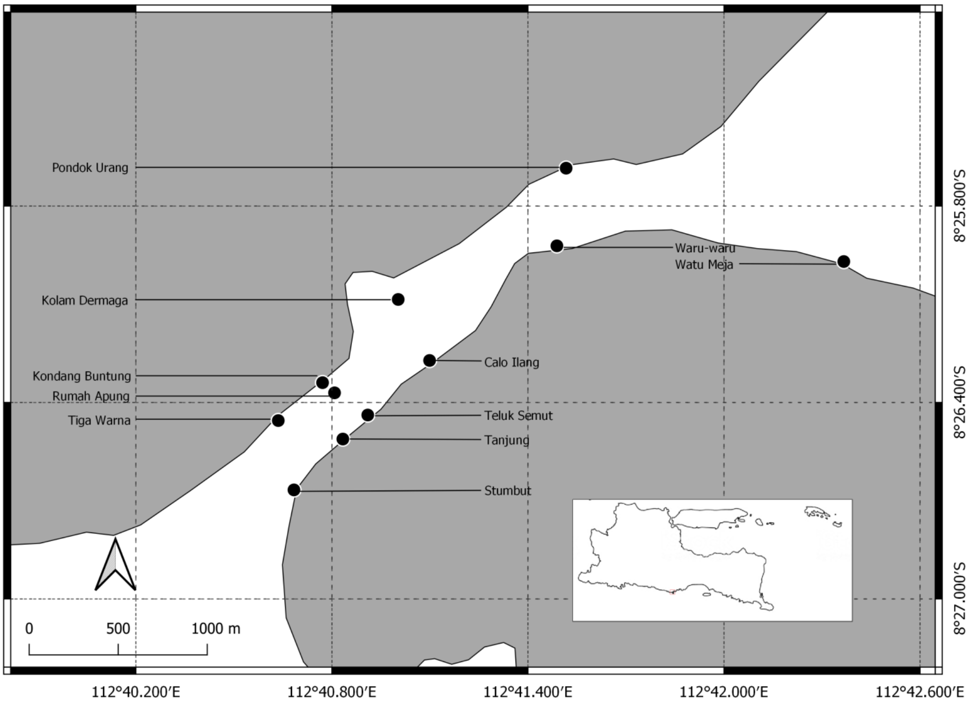

Fig. 1 Sempu Strait map featuring sample locations (black dots). Grey shade represents landmasses, inset represents study location (tiny red square) within East Java Province, Indonesia.

3 Results

A total of 84 species of cryptic marine fauna recorded during the study, in which 45 species belong to sea slug group, 29 species belong to fish group, 8 species belong to arthropod group, and 2 species belong to polyclad flatworm group. Both sea slug and fish groups are the most well-distributed cryptic fauna groups found during the study, in which at least one species could be found on every dive sites. In the other hand, the polyclad flatworm groups only could be found on one dive site during this study, while the arthropod group could be found on five different dive sites.

Figure 2 shows the distribution of cryptic marine fauna at study area. Dive site with the most species of sea slug is Rumah Apung with 19 species recorded, followed by Stumbut with 17 species recorded, while the dive sites with the least number of sea slug species are Waru-waru and Watu Meja with only two species of sea slug recorded on each dive site. In cryptic fish group, Tiga Warna holds the highest number of species with 14 species recorded, followed by Kondang Buntung and Stumbut with 10 species each, while Calo Ilang has the fewest cryptic fishes number with only 3 species recorded. The arthropod group only could be found at Kolam Dermaga, Kondang Buntung, Teluk Semut, Tiga Warna, and Pondok Urang dive sites, with Tiga Warna leads ahead the other dive sites with 6 species recorded, while Kolam Dermaga and Stumbut has the fewest arthropod species with only 2 species recorded. As mentioned before, polyclad flatworm group only could be found at one dive site, which is Teluk Semut with 2 species recorded. Overall, Stumbut has the highest combined species number of all the dive sites during this study with 27 cryptic fauna species recorded, followed by Tiga Warna and Rumah Apung with 25 species each, while Calo Ilang has the fewest cryptic fauna species number with only 6 species recorded.

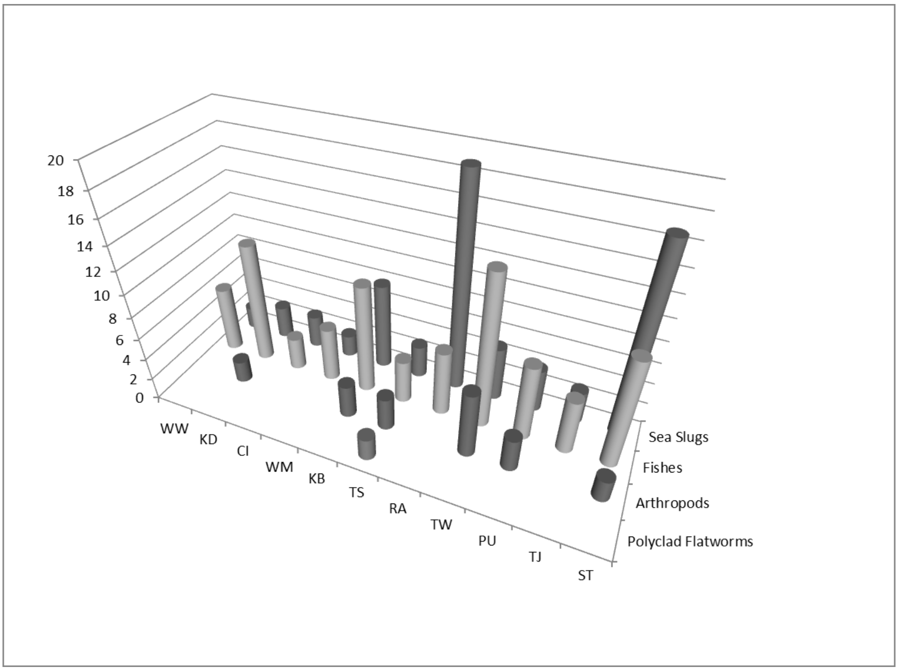

Fig. 2. Cryptic marine fauna group's distribution across the dive sites at study area.

Table 2 shows the distribution of sea slug species on study area, where the most encountered sea slug being *Phyllidiella pustulosa*, in which this species is found on 5 dive sites, followed by *Hypselodoris tryoni* which is found on 4 dive sites during the study. Despite its distribution only limited to Rumah Apung, the Anaspidean *Stylocheilus longicauda* is found on a large assemblage consists of roughly 18 individuals during the study. This assemblage also associated with it closest relative, *Stylocheilus striatus* that also forming an assemblage consists of 15 individuals found during this study. The other sea slug's species with the highest individuals encountered at the same station being the *Bulla ampulla* with 15 individuals, while *Dolabella auricularia* also has the highest recorded individuals with 17 individuals encountered at Kolam Dermaga.

Table 2. Sea slug species distribution on each dive site, numbers denote individuals recorded

Species	*Dive Sites*										
	WW	KD	CI	WM	KB	TS	RA	TW	PU	TJ	ST
Tubulophilinopsis pilsbryi					1						
Aplysia oculifera		3					2				
Bursatella leachii							11				
Dolabella auricularia		17									
Notarchus indicus							7				
Stylocheilus longicauda							18				
Stylocheilus striatus							15				
Dermatobranchus albus							4				

Species	*Dive Sites*										
	WW	KD	CI	WM	KB	TS	RA	TW	PU	TJ	ST
Bornella Anguilla							2				
Bulla ampulla							15				
Chromodoris aspersa											1
Chromodoris sp.											1
Dorisprismatica atromarginata					1						1
Goniobranchus geometricus											1
Goniobranchus reticulatus											1
Hypselodoris dollfusi					1						
Goniobranchus verrieri											1
Hypselodoris apolegma					2						2
Hypselodoris emma					2						
Hypselodoris infucata					2			2			2
Hypselodoris kanga											1
Hypselodoris maculosa							2			1	
Hypselodoris pulchella								5	1	1	
Hypselodoris tryoni					2	3				2	2
Thorunna daniellae									1		
Goniobranchus sp.							1				1
Dendrodoris denisoni							1				
Dendrodoris nigra							1				
Halgerda sp.											1
Eubranchus mandapamensis							2				
Cratena samba							1		1		
Phidiana militaris							3				
Phyllodesmium poindimiei							4				
Pteraeolidia ianthina					1	2		3			
Coryphellina exoptata											1
Coryphellina rubrolineata								2			1
Phyllidia ocellata											1
Phyllidia varicosa	1	2	1								
Phyllidiella pustulosa	1		3					2	2		3
Phyllidiopsis fissurata			2	4		2					
Elysia marginata							1				

Species	*Dive Sites*										
	WW	KD	CI	WM	KB	TS	RA	TW	PU	TJ	ST
Thuridilla lineolata											1
Samla bicolor				1							
Scyllaea fulva							1				
Melibe viridis							1				

WW: Waru-waru, KD: Kolam Dermaga, CI: Calo Ilang, WM: Watu Meja, TS: Teluk Semut, RA: Rumah Apung, TW: Tiga Warna, PU: Pondok Urang, TJ: Tanjung, ST: Stumbut.

Table 3 shows the distribution of cryptic fishes species on study area, where the most encountered fish being *Plectorhinchus vittatus* (juvenile form), in which this species is found on 8 dive sites, followed by *Plagiotremus rhinorhynchos*, *Ostracion cubicus*, and *Pterois volitans* which these species found on 6 dive sites during the study. Fish species with the highest individuals encountered being *Aeoliscus strigatus*, which usually found in a small aggregation that during this study, 22 individuals are being recorded from three dive site. The second fish species with the most individual recorded being the *Plectorhinchus vittatus* (juvenile form), with 11 individuals recorded during this study.

Table 3. Fish species distribution on each dive site, numbers denote individuals recorded

Species	*Dive Sites*										
	WW	KD	CI	WM	KB	TS	RA	TW	PU	TJ	ST
Histrio histrio							2				
Antennarius pictus		1					1				1
Antennarius commersoni								1			
Plagiotremus rhinorhynchos				1		1		1	1	1	1
Petroscirtes variabilis		3									
Aspidontus taeniatus			1					1	1		1
Synchiropus ocellatus					1						
Aeoliscus strigatus		7						5			10
Cryptocentrus leucostictus								1			
Pleurosicya mossambica				1	1			2			
Bryaninops yongei					2						
Amblygobius phalaena					1			1			
Plectorhinchus vittatus	2	1	1	1				2	1	1	2
Plectorhinchus lineatus	1	1		1							
Plectorhinchus polytaenia					1			1			
Aluterus scriptus							1	1			
Ostracion cubicus		1			1	1	1	1	1		
Eurypegasus draconis									1		
Pterois volitans		1				1		2	1	1	1

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Dendrochirus brachypterus		2			1						
Dendrochirus zebra		1						1		1	1
Aseraggodes kaianus		1									
Solenostomus paradoxus					2						2
Micrognathus pygmaeus	1										
Syngnathus biaculeatus	1						5				
Hippocampus hystrix					1						
Hippocampus kuda					2		3				
Synodus dermatogenis	1		1	1		1		1		1	1
Synodus variegatus	1	2							1		2

Table 4 shows the distribution of polyclad flatworms species on study area, where both of the polyclad flatworm species are encountered only within the Teluk Semut dive site. Species with the most individual recorded being the *Cycloporus venetus* with 8 species, followed by *Pseudobiceros fulgor* with 2 species.

Table 4. polyclad flatworm species distribution on each dive site, numbers denote individuals recorded

Species	*Dive Sites*										
	WW	KD	CI	WM	KB	TS	RA	TW	PU	TJ	ST
Cycloporus venetus						8					
Pseudobiceros fulgor						2					

Table 5 shows the distribution of arthropods (crustacean) species on study area, where the most encountered arthropod being *Stenopus hispidus*, in which this species is found on 6 dive sites, followed by *Odontodactylus scyllarus* and *Panulirus versicolor* (juvenile form) in which these species found on 3 dive sites. The most abundant species being the *Stenopus hispidus* with 20 individuals recorded, followed by *Rhynchocinetes durbanensis* with 15 individuals, despite only could be found at Tiga Warna during this study.

Table 5. Arthropod species distribution on each dive site, numbers denote individuals recorded

Species	*Dive Sites*										
	WW	KD	CI	WM	KB	TS	RA	TW	PU	TJ	ST
Odontodactylus scyllarus						1		2	1		
Rhynchocinetes durbanensis								15			
Stenopus hispidus		1			5	5		3	5		1
Xenocarcinus conicus		1			2						
Periclimenes soror					1			2			
Panulirus versicolor						3		5	2		
Trapezia tigrina								1			
Hymenocera picta											2

Ecological indices are numeric expressions that have been derived from quantitative data to express the needs of species on conservation [34]. Shannon-Wiener Diversity Index is one of the ecological indices that interpret the community structure systematics on a specific environment through species variety analysis [36] The Overall diversity of marine lifeforms around Sempu Strait is shown on Fig. 3A, where sea slugs is the cryptic marine fauna group with leading diversity value with 3.32 followed by cryptic fishes with 3.02. These results are showing that Sempu Strait has a high diversity level of heterobranch sea slug and cryptic fishes. Meanwhile, the arthropods and polyclad flatworms diversity values are 1.58 and 0.50 respectively, where these results is showing that Sempu Strait has a medium diversity level of arthropods and low diversity level of polyclad flatworms.

If we see on a site-specific diversity (Fig. 3B), the only dive site with high level of cryptic marine fauna diversity is Stumbut with 3.08, while none of the other site's diversity value could surpass 3. The second dive site with the highest diversity value is Kondang Buntung with 2.91, followed by Tiga Warna with 2.83, Rumah apung with 2.69, Pondok Urang with 2.45, Teluk Semut with 2.22, Kolam Dermaga with 2,19, Waru –waru and Tanjung with 2.04, Watu Meja with 1,74, and Calo Ilang with 1.67. The other ten sites are listed as dive sites with "medium diversity"as their diversity value is greater than 1 but lower than 3.

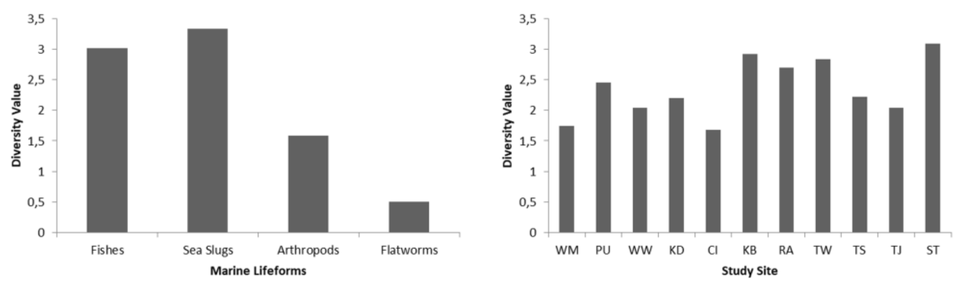

Fig. 3. Overall Shannon-Wiener Diversity Index value on marine lifeforms (A) and dive sites (B) around Sempu Strait

Figure 4 shows site-specific marine cryptic fauna's diversity value. Among the dive sites at the Sempu Strait Waters, the cryptic fishes diversity ranged from the lowest 1.09 (Calo Ilang) to the highest 2.46 (Tiga Warna) the cryptic fishes diversity value between the dive sites around Sempu Strait is considered as "medium diversity" as it is surpass 1, but still below 3. Sea Slug diversity around Sempu Strait ranged from 0.50 (Watu Meja) to 2.75 (Stumbut). Three sites are considered to have "low diversity" of sea slug as they have diversity value below 1, which are Watu Meja (0.50), Kolam Dermaga (0.68) and Waru-waru (0.69), while the other eight sites are considered to have "medium diversity"of sea slug as their diversity value still below 3. The arthropod (crustacean) diversity values are only distributed among 6 dive sites on which we encounter at least one species of arthropods. The overall arthropods (crustacean) diversity shows that five of six dive sites have "low diversity" of arthropods as their diversity values are lower than 1, while Tiga Warna stands solely with diversity value at 1.37, on which it is considered to have "medium diversity"of arthropods. Stumbut has the lowest arthropods diversity among the dive sites studied with 0.63. The polyclad flatworms only could be found at one dive site, which is Teluk Semut, so it is maintaining its diversity value with 0.50, thus is considered to have "low diversity".

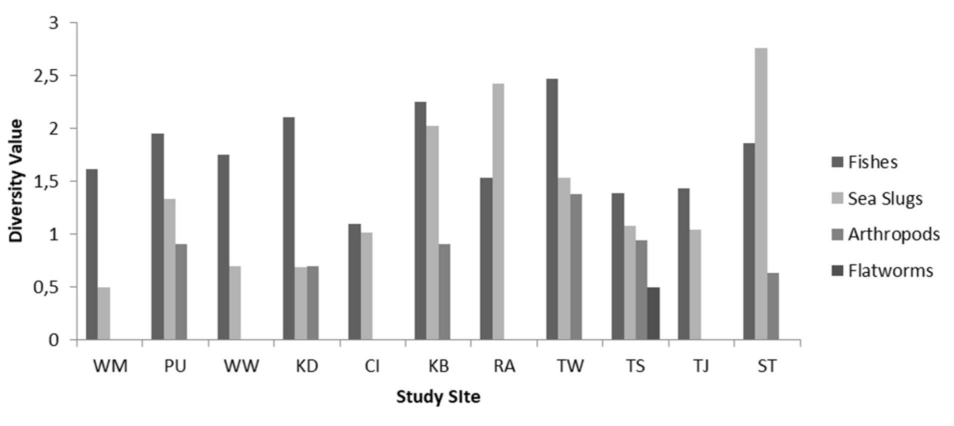

Fig. 4. Shannon-Wiener Diversity Index value between marine lifeforms within dive sites around Sempu Strait

The difference between the cryptic marine fauna group's diversity within the dive sites might be affected by the benthic structure difference between the dive sites, or their respective behaviour itself. The living coral cover around Sempu Strait is ranged from 6.94% – 42.96% with an average around 28.68%. These percentages shows that the coral reef status across Sempu Strait is either heavily damaged, or mildly damaged [37], and is constantly decreasing in some part of the Sempu Strait [38]. This phenomenon is mainly caused by the high sediment level derived either from river runoff (Clungup estuary, Kondang Buntung Estuary, and Tamban River) or sediment runoff that comes directly from the barren land around Sempu Strait waters. This runoff brings a heavy load of sediments into the strait water, and thus limits the growth of reef's coral as coral reefs are very sensitive to sedimentation [39]. But this phenomenon allows other sessile invertebrates to thrive, benefiting the food particle that driven by the currents, such as sponges, ascidians, and cnidarians [32]. These filter feeders also becoming space competitors for hard corals on a benthic community, and thus affecting the living coral cover [40]. A study from Taiwan suggest that nudibranchs are more encountered at abiotic substrate, such as rubble and sand, while they also prefer biotic substrate like sponges and hydroids far more than their preference on a living scleractinians [41]. This is mainly because their feeding habits, where nudibranchs prefer to prey upon sessile invertebrates [22], thus they could be found in a larger diversity, even on an area with low hard coral cover.

While lots of studies suggest that reef fishes are increasing along the increase of living coral covers [42-43] however, cryptic fishes distribution according to some researches, are more affected by their behavioral pattern [44]. Some cryptic fishes are more related to the sandy-bottomed substrate, and they used their ability to burrow inside the sand to protect themselves from predators [19]. Habitat complexity also could influence the abundance of cryptic fishes species. An experiment with artificial reefs with variation in rugosity and hole sizes suggests that fish abundance is affected by changes in rugosity, even it was not increasing significantly. While it rise significantly with the increasing variety of hole size on their benthic substrate [45].

This behavioral-related pattern also observed on arthropods, a study indicate that a lot of decapod crustaceans are living in association with other organisms, like echinoderms, anemones, sponges, corals, molluscs [33], and even fishes [46]. In most symbiotic crustacean, their abundance is highly affected by their host's abundance, and distribution [47]. Some studies also suggest that benthic crustacean assemblages also occur at a larger scale on abiotic microhabitat, especially dead corals [48], where this microhabitat is considered to be the most important habitat for tropical benthic crustacean assemblage as crustacean found in this habitat yields higher biomass and estimated prpoductivity [49].

The existence of polyclad flatworms on the study area might be affected by certain factor. The flatworm *Cycloporus venetus* existence might be affected by the abundance of its prey in the particular dive site. A study suggests that this polyclad flatworm species was seen in association with colonial ascidian *Atriolum robustum*, while it suggests that this kind of ascidias is probably its food [50]. While in the otherhand, benthic structure also could affect the abundance of polyclad flatworm, where a study suggest that the flatworm *Pseudobiceros fulgor* is usually found on under boulders at reef crests [51]

This study suggests that the dive sites around the Western Part of the Sempu Strait have a relatively higher cryptic marine fauna diversity than the Eastern Part of this area. This higher diversity is concentrated on Stumbut, Tiga Warna, and Kondang Buntung dive sites. This result indicates that underwater macrophotography activities could be more focused into that area. However, a better ecotourism management should be prepared and implemented so that the activities won't harm both the existence of cryptic marine faunas around those area and the ecosystem's condition itself. While underwater macrophotography activities are being an increasingly regular activity across the country [10] [52], this study indicates that Sempu Strait has a promising potential to be developed as underwater macrophotography center in Southern East Java and hopefully could give a more sustainable benefit for the local society.

4 Conclusions

Eighty four species of cryptic marine fauna recorded during the study, in which 45 species belong to sea slug group, 29 species belong to fish group, 8 species belong to arthropod group, and 2 species belong to polyclad flatworm group. This study indicates that Sempu Strait area has a high diversity level of heterobranch sea slug and cryptic fishes, while it also has medium diversity of arthropods, and low diversity of polyclad flatworms. Stumbut is the only site to have high diversity of cryptic marine fauna, while the other ten sites are only have medium diversity of cryptic marine fauna. Site-specific diversity shows that overall cryptic marine fauna within the dive sites are listed as medium. Our study shows that dive sites on western part of the strait have a relatively higher diversity than their eastern counterpart, so that underwater macrophotography activities could be more focused on exploring the western part to give the divers a better diving experience.

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